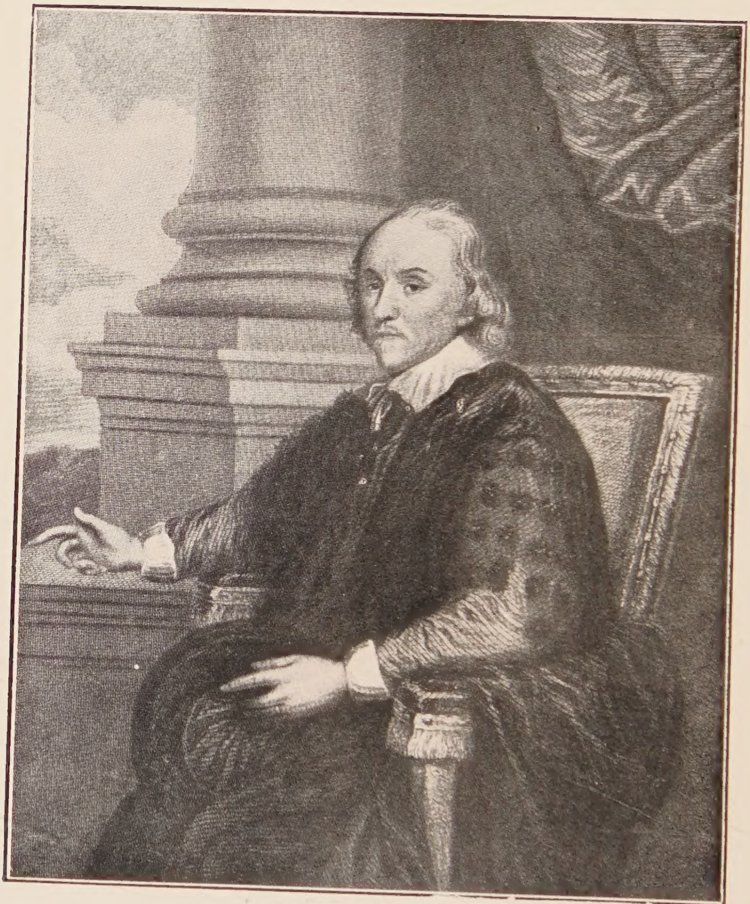
PATHFINDERS OF PHYSIOLOGY

DEMPSTER



—From an engraving.

WILLIAM HARVEY, 1578-1657.

PATHFINDERS OF PHYSIOLOGY

—BY—

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Science

*" * * * I taught them how the stars do rise*
And set in mystery, and devised for them
Number, the inducer of philosophy,
The synthesis of letters, and besides
The artificer of all things, Memory
That sweet Muse-Mother."
---Aeschylus

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FOREWORD

The following pages are the result of the writer's indulgence in biography as a recreation. The title Pathfinders is presumed to describe the contents. The biographical essay, it is hoped, will be the tribute of a stone to the cairn of those who have blazed the trail of discovery in a domain that has meant so much to scientific medicine, for "Destiny reserves for man repose enough." The writer of biography, in his self-appointed task fills a role similar to that of Old Mortality in Scott's well-known novel who visited the graves of the departed and renewed the moss-covered inscriptions on their gravestones. The chapters which constitute this volume have already appeared in the Detroit Medical Journal and are reprinted here with slight alteration. There is no pretense towards a complete history of physiology; far from it. Hence, while the courteous reader will give the writer credit for having read, the critical reader will discover, perhaps, a great deal that he has either overlooked or failed to read. The subject itself abounds with interest; regarding the manner of its presentation, perhaps, not so much may be said. An endeavor has been made to present as much of the human element as available data has permitted. Though the real life of every great man lies in the story of his achievement, rather than in the tale of how he passed his days, yet the human touches find response in the mind of man. "I have remarked," said Carlyle, "that a true delineation of the smallest man and his scene of pilgrimmage through life is capable of interesting the greatest man; each man's life is a strange emblem of every man's and human portraits faithfully drawn are of all pictures the welcomest on human walls."

* * *

The reader of the history of medicine cannot but be impressed by the cosmopolitan nature of the science. National lines are unknown, for thoughtful men of every clime have contributed to its progress. Its beginnings are enveloped in the mazes of ancient superstition, where here and there its fitful light gleamed forth to be succeeded by long centuries of Cimmerian darkness. Owing to veneration for the work of such men as Galen, to the sacredness with which the

lifeless body was viewed and to the slow development of its ancillary sciences the progress of medicine up to the beginning of the nineteenth century was necessarily slow. Medicine, on the whole, however, has advanced during periods of great intellectual activity and during times of intellectual torpor has remained in a quiescent state. The rise and fall of systems and methods would dispose one to wonder if the end is yet; if we have at last reached the bedrock of fact in a scientific sense. The great advantage of truth over error is that though at times crushed to earth, it will rise again. Not until science and philosophy had freed themselves from the throes of ecclesiasticism, was any marked forward movement possible, for, during the first fifteen centuries of the Christian era the most preposterous ideas of physiology obtained, being founded upon the sacred writings and superstitions of the saints. The growth of knowledge through observation was scarcely possible until the priest was no longer physician. With this great event is associated the name of Hippocrates who was the first to make deductions based upon experiment and observation. He lived during the Golden Age when Pericles ruled with mild persuasion; when Phidias made immortal the sculptured art of Greece and Herodotus recorded the history of the illustrious people; when Democritus proclaimed the atomic theory of the universe and Socrates taught that the greatest knowledge was to "Know thyself." Experiment, observation and deduction have been aptly called the tripod of science. Though much that Hippocrates taught has been discarded, yet in the field of clinical observation many of his teachings prevail today. The "facies Hippocrates" still designates the characteristic signs of impending death. We have many accurate descriptions of disease made from careful observations, but perhaps more than all else we owe to him that lofty idealistic note which comes down to us in the Hippocratic oath.

It was not until men disregarded authority and made direct appeal to nature that medicine experienced its renaissance. Such was the method of Harvey, Beaumont and of others whose contributions are of permanent value. The sincere student of nature approaches his subject with an open mind; his is the quest for truth. He possesses "that enthusiasm for truth, that fanaticism for veracity, which is a greater possession than much learning; a nobler gift than the power of increasing knowledge." As Sir Michael Foster once said, "His nature must be one which vibrates in unison with that of which he is in search; the seeker after truth must himself be truthful, truthful with the truthfulness of nature, which is far more imperious, far more exacting than that which man sometimes calls truthfulness." Such is the religio medici.

* * *

Nor is the history of medicine without its martyrs. While scientific inquiry has been the chief instrument in producing a higher and better civilization, it has met at almost every step determined opposition from the powers of ignorance and jealousy. There is great satisfaction in giving to the world those things which all men see and for which all men are grateful. The poet, the painter, the musician and the architect vie with one another in their appeal to the esthetic sense. Yet is there not something higher even than knowledge for the sake of knowledge, or art for art's sake? Yes, there is honor to him who chooses a less spectacular calling, to him who applies scientific knowledge to the conquest of disease. Such men have battled with the enemy unencouraged by the blare of trumpets or the throb of the war drum. They have pursued their work in hospital ward or laboratory, or as "Weelum McLure," have braved the winter storm on errands of mercy to the suffering.

"Speak History! Who are life's victors? Unroll thy long
annals and say;
Are they those whom the world calls victors who won the
success of the day?
The martyrs or Nero? The Spartans who fell at Ther-
mopylae's tryst,
Or the Persians and Xerxes? His Judges, or Socrates?
Pilate or Christ?"

J. H. D.

Among the works by which the writer has been assisted and to which his grateful acknowledgments are due are the following: William Harvey, by D'Arcy Power; Biology and it's Makers, by Locy; Lectures on the History of Physiology and Claude Bernard, by Sir Michael Foster; Harvey's Work on the Circulation, Sydenham Society Edition; Beaumont's Work on Digestion (original copy); Life and Letters of William Beaumont, by Myer; Brain and Personality, by Thompson; Recent Progress of Heredity, Variation and Evolution, by Locke; Heredity, by Thompson; Gorton's History of Medicine; The Relation of Medicine to Philosophy, Moon.—Alabama Student, by Osler.

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"There is no knowledge so useful to man as knowledge of himself. Health and happiness are promoted by it. Before the advent of the modern scientific spirit, biologic knowledge was required to conform to the dominant superstitions of the time. The human body was regarded as a peculiar and awful thing, and not amendable to the laws which govern the rest of the universe. Then it was found that the mechanics of the body are entirely reconsilable with the principles of physics. Humanity's debt of gratitude is incalculably great to those men who at the risk of their lives and fortunes made dissections of dead bodies of men and animals, and discovered the mechanism of the muscular system which imparts motion to the joints, the valvular and pump-like arrangement of the heart, and the hydraulic principles of the tubes which convey the blood through the body. Then came those students of the secrets of nature who discovered that the same laws which govern man govern the lower and the lowest of creatures; that between soil and mineral, fluids and gases, plants and animals, there is no dividing line; that the lily is the daughter of the pool, and the man is the brother of the ox. This knowledge was gotten for us, not by the philosopher among his books, but by the patient investigator who went to the heart of nature and studied her secrets."—J. P. Warbasse.

CHAPTER I.

THE CIRCULATION OF THE BLOOD—WILLIAM HARVEY

"This man lived in an age when alchemy was more popular than science, and the love of mystery stronger than the love of philosophy."—Gorton.

"History is simply the biography of the mind of man; and our interest in history, and its educational value to us, is directly proportionate to the completeness of our study of the individuals through whom this mind has been manifested. To understand clearly our positions in any science today, we must go back to its beginnings, and trace its gradual development, following out our laws, difficult to interpret and often obscured in the brilliancy of achievements—laws which everywhere illustrate this biography, this human endeavor, working through the long ages; and particularly is this the case with that history of the organized experience of the race which we call science."—Sir William Osler.

The Renaissance—The renaissance, that transitional movement in Europe between the mediaeval and modern world, affected medicine and the sciences at a much later date than art and letters. It began with Petrarch and the humanists in the fourteenth century in Italy, where it became manifest in painting and sculpture. The movement was accelerated in the sixteenth century by the capture of Constantinople by the Turks in 1509, and the dispersion of its Greek scholars to the shores of Italy, which event opened anew the science and learning of the ancient world at an hour when the intellectual energy of middle ages had reached its ebb. It is significant to note that Florence, so long the abode of intellectual freedom and art, welcomed with extended arms the exiled Greek scholars. Her traders returned from the East with ancient manuscripts as the most valuable portion of their merchandise. But we are more immediately concerned with the movement as it affected medicine and its allied studies. However much the new learning promoted literature and art, its influence was anything but favorable to the progress of science. Admiration for the literature of ancient Greece while it engendered a love for poetry, history and philosophy, had a similar effect in promoting a spirit of veneration for the writings of Hippocrates, Ptolmey and Galen, so that it became almost an act of impiety to question their teachings. It was not until the sixteenth century, as we shall see, that the spell of ancient authority was broken by the direct appeal to nature. It was not until then that the anatomist determined at all cost to examine the human body for himself and to be guided by his own observations.

Anatomy and Physiology—As anatomy precedes physiology, in order to adequately appreciate the work of Harvey, a brief account of the progress in anatomy is necessary. The great anatomist of antiquity, who surpassed all others, was Galen (130-200 A. D.). He lived for a time at Pergamos and for five years at Rome. He was a man of talent both as observer and writer. His writings embody all the important anatomical discoveries of his predecessors, enriched and much enlarged by the results of his own originality. His observations, however, were made upon the lower animals on the faith of which he

expounded the human subject. Huxley declares that "No one can read Galen's works without being impressed with the marvelous extent and diversity of his knowledge and by his clear grasp of those experimental methods by which alone physiology can be advanced." Rome was the field of his greatest triumph as physician. So great was Galen's influence that for more than a thousand years his works held undisputed sway over anatomical teaching until a greater name arose in the person of Vesalius. Vesalius, born in Brussels the last day of 1514, inherited from an ancestry of learned men a keen appetite for scientific learning. His was that independent, liberty-loving mind which has characterized his countrymen before and since his day. The great importance of his work lies in the fact that he overthrew adherence to authority as a means of arriving at truth and employed instead, observation and reason. Slavish obedience to authority characterized the thought and methods of the Dark Ages. This was in accord with the ecclesiastical influence dominant during this long period. It was the method of the theologian, which had, unfortunately, survived almost to our own day. Darwin was perhaps the most recent object of theological invective. As the Scriptures were an infallable guide to spiritual truth, so the works of Galen were unfailing guides to scientific truth. Vesalius was bitterly opposed not only by the ecclesiastic forces, but by medical men of his time. The theologians opposed him because, among other things, he differed from the widely accepted dogma that man should have one less rib on one side because according to Scripture Eve was formed from one of Adam's ribs. He was also at variance with them on the subject of the Resurrection bone. Vesalius was willing, however, to leave the matter with the theologians, since it did not appear to him to be an anatomical question. Sir Michael Foster writes that Vesalius "Tried to do what others had done before him—he tried to believe Galen rather than his own eyes, but his eyes were too strong for him; and he cast Galen aside and taught only what he could see and what he could make his students see, too. Thus he brought into anatomy the new spirit of the time, and especially the young men of the time answered with a new voice." It is said that students flocked to his lectures, his audience amounting to some five hundred. The history of anatomy precedes that of physiology as a logical sequence. The work of Vesalius placed the structure of the human body in a new light.

William Harvey was the first man to study and proclaim the function of structures which Vesalius had in such a masterly manner demonstrated.

"The work of Harvey," says Locy, "Was complemental to that of Vesalius and we may safely say that, taken together, the work of these two men laid the foundations of the modern method of investigating nature. * * * In what sense the observations of the two men were complimental will be better understood when we remember that there are two aspects in which living organisms should always be considered in biological studies; the first, the structure, and then the use that the structures subserve."

The new learning spread over Europe in a westerly and northerly direction. England was the last to partake of its benign blessing. England had but two universities—Oxford and Cambridge; France

had six; Germany eight; Italy sixteen. Medicine was a prominent department in all of them. Compared with the reception accorded literature and philosophy, science lagged in England. Green sums up the situation (1645): "Bacon had already called men with a trumpet voice to such studies. But in England, at least, Bacon stood before his age. The beginnings of physical science were more slow and timid there than in any country of Europe. Only two discoveries of any real value came from English research before the Restoration —the first, Gilbert's discovery of terrestial magnetism, in the close of Elizabeth's reign; the next, the great discovery of the circulation of the blood which was taught by Harvey in the reign of James. Apart from these illustrious names England took little share in the scientific movement of the continent; and her whole energies seemed to be whirled into the vortex of theology and politics by the Civil War."

Birth and Education—William Harvey was born in Folkstone, England, April 1st, 1578. Very little is known of his early life. His preliminary education was obtained at his native town, where he made his first acquaintance with Latin. He proceeded to the King's School, Cambridge, where he remained five years, and afterward, at 16 years of age, entered Caius College, Cambridge, in 1593. Harvey even early in his school life possessed habits of minute observation. His fondness for dissections and his love for comparative anatomy had shown his mental bias from his earliest years. To Caius, the founder of the College at Cambridge, is accredited the introduction into England of the study of practical anatomy. He obtained for his college a charter which allowed the authorities of the institution to take annually the bodies of two criminals condemned to death and executed at Cambridge, free of all charges, for the purposes of dissection, with the view to increase the knowledge of medicine and to benefit the health of her majesty's lieges, without interference on the part of any of her officers. To what extent the college availed itself of the privilege is not known. In all probability Harvey pursued the course of study which consisted of a sound knowledge of Greek and Latin ordinarily followed until he obtained his B. A. degree in 1597. A year after graduation, at the age of twenty, we find him traveling on the continent where he studied the scientific branches tributary to medicine, as well as medicine itself. As has been said, the universities of northern Italy were the first to welcome the new learning as it emanated from the east in the minds of Greek scholars, as well as rescued manuscripts. The universities of northern Italy, namely, Bologna, Padua, Pisa and Pavia, were at the time at the height of their renown as centers of mathematics, law and medicine. Harvey studied more particularly at Padua, renowned for its anatomical school, and rendered famous by the work of such men as Vesalius, the first of modern anatomists, and his successor, Fabricius. The tolerance shown towards Protestants in Padua, the university town of Venice, the great commercial republic, attracted many law and medical students from England and other Protestant countries of Europe.

It is interesting to recall that each entry in the university (Padua) register was accompanied by a note describing some physical pecularity of the student, as a means of his identification. Thus Johannes Cookaeus, Anglus cum cicatrice in articulo medii digiti die

dicta. John Cook, an Englishman, with a scar over the joint of his middle finger. (Matriculated) on the same day, and so on. Harvey evidently did not enter Padua University as a regular matriculant, as no such record occurs on the university register regarding him.

Fabricius and Harvey Friends—The fame of some of its medical teachers undoubtedly attracted Harvey to Padua. While there he was instructed in anatomy and physiology by Fabricius, one of the most learned scholars of Italy. The fame as anatomist and surgeon of Fabricus ab Aquapendente (from the name of his birthplace) had spread well over Europe. During Harvey's sojourn in Padua he and Fabricius became fast friends. At that particular time Fabricius was engaged in perfecting his knowledge of the valves of the veins. His idea was that these valves prevented over-distention of the vessels when the blood passed from the large to the smaller veins, while they were not required in the arteries because the blood was always in a state of ebb and flow. Harvey, however, pointed out their true importance as anatomical proof of the circulation of the blood. It was not so much what Harvey learned from Fabricius, as the stimulus of his friendship that proved of such great assistance to him, for we can see even in the instance quoted his view of the purpose of the valves of the veins was entirely incorrect.

In 1602, Harvey was graduated M. D. from Padua. His diploma conferred upon him the degree of Doctor of Physic, with leave to practice and teach arts and medicine in every land and seat of learning. It further stated, that "he had conducted himself so wonderfully well in the examination and had shown such skill, memory and learning that he had far surpassed even the greatest hopes which his examiners had formed of him. They decided, therefore, that he was skillful, expert and most efficiently qualified both in arts and medicine, and to this they put their hands unanimously, willingly and with complete agreement and unhesitatingly." The University of Cambridge conferred the degree of M. D. on him the same year.

Harvey married in 1604, the daughter of Dr. Browne, who was physician to Queen Elizabeth and to James I.

Harvey, as we shall see, excelled as lecturer. His lectures showed an intimate acquaintance with the anatomical structure of more than sixty kinds of animals, as well as a thorough knowledge of human anatomy, which must have taken years of study to acquire. He was elected fellow of the College of Physicians in 1607. An important position which Harvey held was Physician to St. Bartholomew's Hospital in 1609. "The charge of the Physician of St. Bartholomew's Hospital" required the incumbent to devote at least one day a week throughout the year to charity. He was further enjoined, "not for favour, lucre, or gain, to appoint or write anything for the poor but such good and wholesome things as he shall think with his best advice will do the poor good, without any affection or respect to be had to the apothecary. And he shall take no gift or reward of any of the poor of this house for his counsel." This "charge" Harvey is said to have faithfully observed.

Anatomical Teaching Previous to 1745—During Harvey's day and until 1745, the teaching of Anatomy in England was vested in a few corporate bodies. Private teaching was discouraged by fine and

imprisonment. The College of Physicians and Barber Surgeons had a monopoly in London. The value of Anatomy as a foundation to medicine was fully recognized at the time . The subjects for dissection were the bodies of executed criminals. Those were the times of public executions, witnessed by immense crowds whose opposition and sympathy for the felon and his friends often interfered with the procuring of the body for dissection.

The method of anatomical instruction is of interest. The subject was taught practically by a series of demonstrations on the body. The absence of means of preservation of cadavers precluded instruction in detail. A single body was dissected to show the muscles; another to demonstrate the bones, and a third to exhibit the viscera. Attendance on anatomical lectures and demonstrations was compulsory; violation meant the forfeiture of a fine. Some were exempted from the penalty, as one entry shows that a Robert Mudsley "has licence to be absent from all lectures without payment of any fine, because he has given over the art of surgery, and doth occupy only a silk shop and shave."

The anatomical demonstrations were open to the public. The following note appears in Pepy's Diary:* "Up and to my office. . . . Commissioner Pett and I walked to Chyrurgeon's Hall (we being all invited thither, and promised to dine there), where we were led into the Theater; and by and by comes the reader, Dr. Tearne, with the master and company in a very handsome manner; and all being settled, he began his lecture, this being the second upon the ureters and kidneys, which was very fine; and his discourse being ended, we walked into the hall, and there being a great store of company, we had a fine dinner and good learned company, many Doctors of Physique, and we used with extraordinary great respect . . . After dinner Dr. Scarborough took some of his friends, and I went along with them to see the body alone, which we did, which was a lusty fellow, a seaman that was hanged for a robbery. I did touch the dead body with my bare hand; it felt cold, but methought it was a very unpleasant sight. . . . Thence we went into a private room where I perceive they prepare the bodies, and there were the kidneys and ureters, etc., upon which he read today, and the doctor, upon my desire and the company's, did show very clearly the manner of the disease of the stone and the cutting and all other questions that I could think of." Pepy's interest in the operation of cutting for stone is said to be due to the fact that he had undergone the ordeal himself. The Dr. Scarborough mentioned in Pepy's note was a friend and pupil of Harvey.

Personal Characteristics—Harvey is described as a man of the "lowest stature, round faced, with a complexion like the wainscot; his eyes small, round, very black and full of spirit, his hair black as a raven and curling; rapid in his utterance, chivalric even to gesture, and used when in discourse with anyone to play unconsciously with

*Samuel Pepys (1632-1703), was a famous diarist. His Diary, which extends from 1660 to 1669, was written in shorthand, and was deciphered by Lord Braybrooke in 1825. This delightful book of gossip is one of the most interesting memorials of the domestic life of the time.

the small dagger he wore by his side." His individuality was marked, as was evidenced by the strong impression he made upon those with whom he came in contact. His intellectual power and independence of character were unusual. His interests were wider than his scientific studies. According to an anonymous biographer* of the eighteenth century, "He was well read in ancient and modern history; and when he was wearied with too close attention to the study of nature, he would relax his mind by discoursing to his friends on political subjects and the state of public affairs. He took great pleasure in reading from the ancient poets, and especially Virgil, with whose work he was exceedingly delighted. He was laboriously studious, regular and virtuous in his life and had a strong sense of religion. In his familiar conversation there was a mixture of gravity and cheerfulness; he expressed himself with great perspicuity, and with much grace and dignity; and was eminent for his great candor and moderation. He never endeavored to detract from the merit of other men; but appeared always to think that the virtues of others were to be imitated and not envied."

In spite of his choleric and hasty disposition he had the faculty of making close friendships. His replies to his critics showed great moderation. Harvey's true character is probably best seen in that period of his life which was beset with opposition and reproach, immediately following the publication of his great work on the circulation. To his traducers his attitude resembled that of the divine Master, "To return evil speaking with evil speaking I hold to be unworthy of a philosopher and searcher after truth. I believe I shall do better and more advisedly if I meet so many indications of ill-breeding with the light of faithful and conclusive observation." His attitude also resembles that of Darwin who, on the publication of his Origin of the Species, was met with a storm of abuse from clerical ignorance. It is said that the great evolutionist not only observed a tranquility impassionate and unique but even condescended to reply at length with courtesy to the rantings of those who vilified without even reading his work or comprehending the object of their denunciations.

Harvey was not a religious man in the narrow sense of the term despite the fact that he lived in an age of warring creeds. His views were broad as befitted a student of the design and workmanship of the Great Architect of the universe. According to Sir Russell Reynolds, "a devout and reverential recognition of God" permeated his work, "not only as the great primal ever-acting force, defined outside and before all the works of nature; but as the Being, 'the Almighty and Eternal God' to whom he says in his last will and testament, 'I do most humbly render my soul to Him who gave it; and to my blessed Lord and Saviour Jesus Christ.'"

Harvey's knowledge of Latin was so thorough that he could converse with facility equal to his native tongue. He was accustomed to employ both English and Latin even in the same sentence, for example, speaking of the eyes and their function: "Oculi eodem loco, viz, nobilissimi supra et ante ad processus eminentes instar capitis in a lobster snayles cornubus tactu pro visu utuntur unde oculi as a centinell to the army locis editis anterioribus."

*British Biographies, Vol. IV., London, 1768.

Harvey as Lecturer—Harvey's lectures were partly read and partly oral. The cadaver lay on the table with the dissecting instruments close to it. An assistant dissected or demonstrated while the lecturer read his remarks. The anatomical lecturer of the sixteenth century was a personage of importance. The greatest consideration was exercised for his personal comfort. The stewards were instructed, "to see and to provide that there be a mat about the hearth in the hall that the Doctor be made not to take cold upon his feet. * * * And further, that there be two fine white rods appointed for the Doctor to touch the body where it shall please him; and a wax candle to look into the body, and that there be always for the Doctor two aprons to be from the shoulder downward and two pair of sleeves for his whole arm. . . . and not to occupy one apron and one pair of sleeves every day, which is unseemly." Harvey laid down the following precepts for his own guidance as lecture precepts which the modern anatomical lecturer might observe with propriety:

(1) To show as much as may be at a glance, the whole belly for instance, and afterwards to subdivide the parts according to their position and relations.

(2) To point out what is peculiar to the actual body being dissected.

(3) To supply only by speech what cannot be shown on your own credit and authority.

(4) To cut up as much as may be in the sight of the audience.

(5) To enforce the right opinion by remarks down from far and near and to illustrate more by the structure of animals according to the Socratic rule.

(6) Not to praise or dispraise other anatomists, for all did well and there was some excuse even for those who are in error.

(7) Not to dispute with others.

(8) To state things briefly and plainly.

(9) Not to speak of anything which can be explained without the body or can be read at home.

Here we have a combination of orthodox medical ethics and sound pedagogy. Harvey's particular role as *Lumlian lecturer included the position of lecturer upon the viscera. Discussing the thoracic viscera he ennunciated the remarkable discovery with which his name is inseparably associated, initialing the notes to indicate that the ideas were peculiarly his own.

constat per fabricam cordis sanguinem.
per pulmones in Aortam perpetuo.
Transferri, as by two clacks of a
water bellows to rayse water.
constat per ligaturam transitum saguinis
ab arteriis ad venas
unde perpetuum sanguinis motum
in circulo fieri pulsu cordis.

W. H.

*The Lumlian lecture was a surgical lecture established at a cost of £40 a year, which sum accrued from the rental of lands of Lord Lumley, of Essex, England.

"It is plain from the structure of the heart that the blood is passed continuously through the lungs to the aorta as by the two clacks of a water bellows to raise water.

"It is shown by the application of a ligature that the passage of the blood is from the arteries into the veins.

"Whence it follows that the movement of the blood is constantly in a circle and is brought about by the beat of the heart." It was not until twelve years after this important announcement that he proclaimed it to a wider audience.

Harvey's literary style was somewhat figurative. He loved to indulge in metaphors—witness:

An cerebrum rex, whether the brain is king.

Nervi majistratus, the nerves his ministers.

Musculi cives populus, the muscles the, citizens or the people.

He also draws a similtude liking the brain to a military commander, the leader of an orchestra, an architect, and he speaks of the muscles and nerves as subordinate officers.

Year by year Harvey delivered the Lumlian lectures to the College of Physicians. His private practice grew so as to be fairly lucrative.

Harvey and Bacon—In 1618 he was appointed physician to James I. In 1631 he was appointed physician in ordinary to King James' son, Charles I. Not only gained he an entrance to the household of the king but he was employed in the homes of the most distinguished nobles. Among others he attended Sir Francis Bacon, who was always a weak and ailing man with a disposition to be hypochondriac. "In William Harvey and Francis Bacon," says Gorton, may be observed two men like planets in conjunction; born in the same generation, each illustrious in the annals of history, the one in philosophy, the other in science but in striking contrast to each other. The one was a thinker, the other was an actor; one conceived methods, the other put methods into operation; one was an academic philosopher, the other a man of science and discovery; one immortalized himself by his profundity of thought, the other by his contribution to science. Both were stars in the firmament of great men, but long after one has become dim or gone out, the other will continue to shine with splendor."

Though honored by England's Lord Chancellor as the custodian of his health, Harvey evidently failed to be impressed with Bacon's greatness even as philosopher, for speaking of him, Harvey refers to him as "writing philosophy like a Lord Chancellor."

Publication of His Work on the Circulation—In 1628, the crowning event of his life took place when he published his well considered and matured account of the circulation of the blood. He had demonstrated his ideas of the circulation for twelve years before publishing them, which event occurred in the fiftieth year of his life. This monumental work of the great physiologist was accomplished while yet in his thirties. Why Harvey should allow so much time to elapse between the event of his epochal discovery and its publication is not clear. Evidently the passion to rush into print was not so great as it is with the investigator of to day. It is interesting to note, how-

ever, that among the greatest thinkers and investigators Harvey is not unique in this respect. Copernicus is said to have detained his "Treatise of Revolutions" thirty years before permitting its publication; Bacon kept his Novum Organum by him for twelve years; Isaac Newton "brooded in silence over the motion of the spheres" for more than twenty years before publishing his Principia; between the first draft and the publication of the Origin of the Species seventeen years were permitted to intervene. Perhaps it was Harvey's reluctance toward "quitting the peaceful haven," that constrained him for so long a time, for elsewhere he tells us that his practice fell off or, to use his own words, he "fell mighty in practice." Regarding him a contemporary wrote, "though all of his profession would allow him to be an excellent anatomist, I never heard of any who admired his therapeutic way. I knew several practitioners in this town that would not have given three pence for his bills (prescriptions) as a man can hardly tell by his bills what he did aim at." Harvey is said to have been the first to be persecuted by the medical profession for making discoveries at variance with the drift of public thought and opinion. The story of all discoveries of the first rank has borne out Locke's aphorism that "Truth scarce ever yet carried by vote at its first appearance." The greatest obstacle to the acceptance of truth seems to be our present knowledge. Men are by nature conservative; they resent innovations. Bagehot tells us that the "pain of a new idea is one of the greatest pains to human nature." Socrates somewhere likens himself to a midwife but his peculiar function in life was to assist in that mental labor which gave birth to ideas, a similitude which is suggestive of pain. The man who expresses a new idea is apt to be abused, perhaps stoned. Whatever may be said of the twentieth century the scientific world can be accused no longer of tardiness in the acceptance of new truth, but it reserves the right to "prove all things and to hold fast to that which is good." While Harvey's practice may have fallen off, his discovery did not by any means consign him to obscurity. He still found favor with King Charles I, whose personal physician he was. His constant attendance at court greatly interfered with his duties at St .Bartholomew's Hospital and resulted in the appointment of an assistant, but with no diminution in Harvey's stipend. A contemporary of Harvey states as follows: "I have heard him say that after his Booke of Circulation of the Blood came out he fell mightily in practice, and 'twas believed by the vulgar that he was crack-brained, and all the physicians were against him, with much adoe at last in about twenty or thirty years' time it was received in all the universities of the world, and as Dr. Hobbs says in his book 'De Corpore,' he is the only man perhaps that ever lived to see his own doctrine established in his lifetime;" **veritas est magna et prevalebit!**

And yet, after the discovery has been recognized as one of momentous import, the scientist has his detractors. Harvey was no exception. There were those who sought to disprove the originality of his work. Some attributed the merit of discovering the circulation to Servetus, some to Realdus Columbus, others to Caesalpinus. True, Servetus, a Spaniard, born in 1511 and burned at the stake in Geneva, 1533, at the bidding of Calvin, in a copy of his Restitutio, which was saved when an edition of 1,000 copies met the fate of the author, rejected the contention that the blood passed through the

cardiac septum. He had grasped the true features of the pulmonary circulation—the passage of the blood from the right side to the lungs, thence to the left side or ventricle. Realdus Columbus, born at Cremona, 1516, a presumptuous personage, speaks of the blood carried, "by the artery-like vein to the lung and being there made thin is brought back thence together with air by the vein-like artery to the left ventricle of the heart." Then he goes on to press his claim by declaring that, hitherto, no one had made this observation or recorded it in writing. Andreas Caesalpinus was born at Arezzo in 1519. He held for many years the professorship of medicine at Pisa. Learned in all the lore of the ancients, he was noted among other things for his determined opposition to Galen; Caesalpinus appears to have grasped one important truth, namely, that the heart at systole discharges its contents into the aorta and pulmonary artery, and at its diastole receives blood from the vena cava and pulmonary vein.

Let all this be granted, yet the great work of Harvey is not a whit less meritorious. The steam engine was in existence before the day of James Watt, yet his name is inseparably associated with the invention which transformed a mere toy into a gigantic factor which has revolutionized human industry. No person, not even the genius is independent of his time; he is the heir of all the ages, and his greatness does not depend so much in presenting something unprecedented as it does in seeing something clearly and telling in a simple way what he has seen.

Treatise on the Circulation.—Harvey's greatest work was undoubtedly his Exercitatio Anatomica de Motu Cordis et Sanguinis in Animalibus, an anatomical treatise on the movement of the heart and blood in animals, published in Frankfort, Germany, in 1628. The book was a small quarto volume of 72 pages. It opens with a dedication to "The Most Illustrious and Indomitable Prince, Charles, King of Great Britain, France, and Ireland, Defender of the Faith," etc. The dedication proceeds: "The heart of animals is the foundation of their life, the sovereign of everything within them, the sun of their microcosm, that upon which all growth depends, from which all power proceeds. The king in like manner, is the foundation of his kingdom, the sun of the world around him, the heart of the republic, the fountain whence all power, all grace doth flow." Whatever may be said regarding Charles I, who was the victim of public execution, he certainly befriended Harvey. Then to the president of the Royal College of Physicians and to other learned physicians the author addresses himself in a dedication which he concludes: * * * "I profess both to learn and to teach anatomy not from books but from dissections; not from the positions of philosphers but from the fabric of nature. * * * I avow myself the partisan of truth alone; and I can indeed say that I have used all my endeavors, bestowed all my pains on an attempt to produce something that should be agreeable to the good, profitable to the learned, and useful to letters." Harvey's method here ennunciated is the method of every scientist since his day, whose contribution has possessed real merit—that is, reasoning based upon experiment and observation.

The work on the circulation comprises seventeen short chapters. It is an interesting account, lucid and connected, of the heart's action and the circulation of the blood. Harvey had no means of knowing

the connection between the smallest arteries and the smallest veins, for the microscope was not in such a stage of perfection as to permit of much fine work in minute anatomy. It was not until the invention of the compound microscope in 1675 that Leeuwenhoek described blood corpuscles and the capillary circulation. In the first chapter the author reviews some of the fantastic theories regarding the functioning of heart and lungs. The heart was held to be the great heat center of the body. The blood was sucked into it during diastole and expelled from it during systole. The arteries cooled the blood; the lungs fanned and cooled the heart. The term "spirits" meant a great deal to Harvey's predecessors, but not to him. "The word blood has nothing of grandiloquence about it, for it signifies a substance which we have before our eyes and can touch; but before such titles as spirit and calidum innatum (inherent heat) we stand agape."

Chapter I, he continues:

"When I first gave my mind to vivisections, as a means of discovering the motions and uses of the heart, and sought to discover these from actual inspection, and not from the writings of others, I found the task so truly arduous, so full of difficulties, that I was almost tempted to think, with Fracastorius, that the motion of the heart was only to be comprehended by God. For I could neither rightly perceive at first the systole and when the diastole took place, nor when and where dilatation and contraction occurred, by reason of the rapidity of the motion, which in many animals is accomplished in the twinkling of an eye, coming and going like a flash of lightning; so that the systole presented itself to me now from this point, now from that; the diastole the same; and then everything was reversed, the motions occurring, as it seemed, variously and confusedly together. * * *

"At length, and by using greater and daily diligence, having frequent recourse to vivisections, employing a variety of animals for the purpose, and collating numerous observations, I thought that I had attained to the truth, that I should extricate myself and escape from this labyrinth, and that I had discovered what I so much desired, both the motion and the use of the heart and arteries; since which time I have not hesitated to expose my views upon these subjects, not only in private to my friends but also in public, in my anatomical lectures after the manner of the academy of old."

He goes on to tell how his views pleased some, displeased others.

He finds it advantageous to study the movement of the heart in the cold-blooded animals—frogs, snakes and fishes. He ascertained that the heart was a muscular organ, that its systole was the result of muscular contraction. The contraction of the heart was more important than its dilitation. "During its contraction the heart becomes erect, hard and diminished in size, so that the ventricles become smaller and are so made more apt to expel their charge of blood. Indeed, if the ventricle be pierced the blood will be projected forcibly outward at each pulsation when the heart is tense." Harvey showed that the pulsation of the arteries depended upon the contraction of the left ventricle. The contraction of the right ventricle propelled

*The extracts which follow illustrate Harvey's style. The Motion of the Heart and Blood, by William Harvey, can be procured in convenient form in the Everyman's Library Series (E. P. Dutton & Co., New York). This is a reprint from the Sydenham Society's edition of 1847.

the blood into the pulmonary arteries, the pulsations of which were simultaneous with the other arteries of the body. He demonstrated that the two ventricles contracted simultaneously and that the two auricles contracted at the same time.

Motion, Action and Office of the Heart.—In the fifth chapter Harvey deals with the motion and function of the heart. It reads somewhat like a modern work in physiology.

"First of all, the auricle contracts, and in the course of its contraction throws the blood (which it contains in ample quantity as the head of the veins, the storehouse, and cistern of the blood), into the ventricle, which, being filled, the heart raises itself straightway, makes all its fibres tense, contracts the ventricles, and performs a beat, by which beat it immediately sends the blood supplied to it by the auricle into the arteries; the right ventricle sending its charge into the lungs by the vessel which is called vena-arteriosa, but which, in structure and function, and all things else, is an artery; the left ventricle sending its charge into the aorta, and through this by the arteries to the body at large. These two motions, one of the ventricles, another of the auricles, take place consecutively, but in such a manner that there is a kind of harmony or rhythm preserved between them, the two concurring in such wise that but one motion is apparent, especially in the warmer blooded animals, in which the movements in question are rapid."

So far as Harvey's reasoning is based upon his observations his conclusions are in the main correct, as proved by more recent research; where he indulges in speculation we get the following:

"In the larger and more perfect animals of mature age Nature has rather chosen to make the blood percolate the parenchyma of the lungs. * * * It must be because the larger and more perfect animals are warmer, and when adult their heat greater, ignited I may say and requiring to be damped or mitigated, that the blood is sent through the lungs, in order that it may be tempered by the air that is inspired and prevented from boiling up and so becoming extinguished or something else of the sort," or, to modernize it, the lungs serve as radiator and the heart the gasoline or internal combustion engine.

Capillary Circulation.—Since Harvey's time Malpighi, in 1661, hinted at the capillary circulation, which was still further investigated by Leuwenhoek in 1674, who studied it with his microscope in the web of a frog's foot and in other transparent membranes. In 1676, Blankaart, and in 1697 Cowper, studied the arrangement of the capillaries by means of injected specimens. A long interval elapsed between the histological study of the circulation before chemistry was sufficiently advanced to afford definite knowledge in regard to oxidation of the blood and the explanation of the true function of the lungs. The work of Priestly in 1775 was a notable contribution to the physiology of respiration. The nineteenth century, through the work of Ludwig in Germany, Chauveau in France, and Foster in England, has seen the physics of the heart and circulation reduced almost to an exact science.

Any account of the works of Harvey would be incomplete were no mention made of his work in embryology. Harvey discussed the nature of development and exhibited extraordinary powers as re-

gards accuracy of reasoning. He may be considered as having made the first independent advance in the subject. That he did not accomplish more was due to lack of instruments of precision, and to the fact that he had to build on the general level of the science of the time. His work on embryology was published in 1651. It was entitled "Exercitationes de Generatione Animalium." In it is an account of not only the development of the chick, but of deer and other mammals as well.

All honor to him who blazes the trail. The refinements, whatever they may be, can never merit for the investigator the honor which is due the pioneer. As was said by Haller, one of the best informed minds of the eighteenth century, "It is not to Caesalpinus, because of some words of doubtful meaning, but to Harvey, the able writer, the laborious contriver of so many experiments, the staid propounder of all the arguments available in his day, that the immortal glory of having discovered the circulation of the blood is to be assigned."

One of his last acts was to set aside a certain sum derived from his estate for the delivery of an oration in commemoration of the benefactors of the College of Physicians. This oration, the Harveian Oration, is still delivered each year by some distinguished member of the medical profession. Even in his declining years his thoughts were turned to the future. The Harveian Lecture is intended to further the progress of science, especially a knowledge of the body in health and disease. "Much of the nobility of the profession," says Osler, Harveian lecturer, 1906, "depends upon the great cloud of witnesses' who pass into the silent land—pass and leave no sign, becoming as though they had never been born. And it was the pathos of this fate not less prophetic because common to all but the few, that wrung from the poet that sadly true comparison of the race of man to the race of the leaves." Harvey was one of the "few" to have achieved that immortality which places him with "The divine men of old time."

He died June 3rd, 1657, in the eightieth year of his age.

Asellius and the Lymphatic Circulation.

Corollary to the circulation of the blood is the lymphatic circulation. The discovery of the lymphatics was almost synchronous with that with which Harvey achieved an immortal name. While the memory of Harvey has been fittingly honored in various ways, that of Asellius or Aselli has not been sufficiently recognized. The data referring to Aselli's life are extremely meagre. He was born in 1581, at Cremona, Italy, the descendant of a patrician family. He studied at the University of Pavia, where he became laureate in medicine, surgery and philosophy, after which he located in Milan, where he taught anatomy privately and engaged in the practice of surgery. It was while in Milan that he made his discovery, in 1622, of the lymphatic vessels which he called venae lactae. His discovery was recognized by his election, two years later, to the chair of anatomy and surgery in his alma mater, a position he was destined not long to hold, for he died in 1626 at the age of forty-five. His book De Lactibus was published a year after his death. William Harvey was

forty-four years old at the time of Aselli's discovery. Aselli's discovery of the lacteals is related by himself as follows:

"On the 23rd of July in that year (1622) I had taken a dog in good condition and well fed, for a vivisection at the request of some friends, who very much wished to see the recurrent nerves. When I had finished this demonstration of the nerves, it seemed good to watch the movements of the diaphragm in the same dog, at the same operation. While I was attempting this, and for that purpose had opened the abdomen and was pulling down with my hand the intestines and stomach gathered together into a mass, I suddenly beheld a great number of cords, as it were, exceedingly thin and beautifully white, scattered all over the whole of the mesentery and the intestine, and starting from almost innumerable beginnings. At first I did not delay, thinking them to be nerves. But presently I saw I was mistaken in this, since I noticed the nerves belonging to the intestine were distinct from these cords and wholly unlike them, and, besides, were distributed quite separately from them. Wherefore struck by the novelty of the thing, I stood for some time silent while there came to my mind the various disputes, rich in personal quarrels no less than in words, taking place among anatomists concerning the mesariac veins and their function. And by chance it happened that a few days before I had looked into a little book by Johannes Costaeus written about this very matter. When I gathered my wits together for the sake of the experiment, having laid hold of a very sharp scalpel, I pricked one of those cords, and indeed one of the largest of them. I had scarcely touched it, when I saw a white liquid like milk or cream forthwish gush out. Seeing this, I could hardly restrain my delight, and turning to those who were standing by, to Alexander Tadinus, and more particularly to Senator Septalius, who was both a member of the great college of the Order of Physicians and, while I am writing this, the medical officer of health, 'Eureka,' I exclaimed with Archimedes, and at the same time invited them to the interesting spectacle of such an unusual phenomenon. And they indeed were much struck with the novelty of the thing."

Aselli noted the presence of valves in the lymphatic vessels and recognized their function, namely, to prevent the backward flow of the lymph. He recognized also that the lacteals were vessels for conveying chyle away from the intestine. He went wrong, however, in regard to the ultimate course taken by the newly-discovered vessels, for he thought he could trace them to the liver. Aselli was heavily handicapped by his previous learning, which consisted of a careful study of as well as veneration for the teachings of the ancients. Galen had, in fact, taught that all nutritive material from digestive processes passed through the liver. Aselli speaks in his book of a group of lymphatic glands lying in the mesentery, as the pancreas—hence the name pancreas Aselli. The force which caused the movement of the fluid in the lacteal vessels was believed by him to be twofold, a **vis a tergo** and a **vis a fronte**; the latter derived from supposed suction of the liver and the former supplied by the movements of the intestines.

Aselli Opposed by Harvey. Aselli in his modesty endeavored to prove that the lacteals were known to the ancients, especially to Herophilus and Erasistratus, founders of the Alexandrine school of medicine. His discovery met the same opposition as did Harvey's, and from the same men, among them Riolan and Primrose, and strange to say Harvey himself failed to recognize the importance of the work

of his contemporary. In a private letter written in April, 1652, he writes:

"With regard to the lacteal veins discovered by Aselli, and by the further diligence of Pecquet, who discovered the receptacle or reservoir of the chyle, and traced the canals thence to the sub-clavian veins, I shall tell you freely, since you ask me, what I think of them. I had already, in the course of my dissections, I venture to say even before Aselli had published his book, observed these white canals. * * * But, for various reasons, and led by several experiments, I could never be brought to believe that that milky fluid was chyle, conducted thither from the intestines, and distributed to all parts of the body for their nourishment; but that it was rather met with occasionally and by accident, and proceeded from too ample supply of nourishment and a peculiar vigor of concoction;" and Harvey continues: "Why indeed, should we not as well believe that the chyle (digested contents of the intestines) enters the mouth of the mesenteric veins and in this way becomes immediately mingled with the blood, where it might receive digestion and perfection. * * * And that the thing is so in fact, I find an argument in the distribution of innumerable arteries and veins to the intestines, more than to any other part of the body, in the same way as the uterus abounds in blood vessels during the period of pregnancy."

Sir William Osler (Harveian oration, 1906) refers to this incident in Harvey's career: "How eminent so ever a man may become in science, he is very apt to carry with him errors which were in vogue when he was young—errors that darken his understanding, and make him incapable of accepting even the most obvious truths. It is a great consolation to know that Harvey came within the range of this law—in the matter of the lymphatic system; it is the most human touch in his career."

The lacteals were demonstrated in man in 1628, the subject being an executed criminal examined shortly after execution. Twenty-one years after Aselli's death the thoracic duct was discovered by Johannes Pecquet, of Dieppe, France. He not only accurately described these lymphatic structures, but showed that Aselli's lacteals poured their contents into what he called the receptaculum chyli, but that the thoracic duct—a continuation of the receptacle—poured its contents into the venous system at the junction of the jugular and subclavian veins. Pecquet was twenty-five years old when he made this discovery, which he himself described as the gift of fortune sporting with the ignorant. Munus est fortunae cum inscio ludentis. Pecquet, however, did not follow up this solitary triumph. His appetite for alcoholic beverages got the better of him and eventually caused his death.

Harvey's work on the circulation appeared between the discovery of Aselli and that of Pecquet and so profoundly had it influenced the medical thought of the time, that the discovery of the thoracic duct and its function was accepted without question.

CHAPTER II.

PHYSIOLOGY OF DIGESTION IN THE SEVENTEENTH AND EIGHTEENTH CENTURIES

The circulation of the blood was worked out and proclaimed to the world by one man, and his work was so complete that it has not been rendered obsolete by subsequent knowledge. The history of the physiology of digestion has been of gradual growth so that no one man can claim credit for our present knowledge. Before the development of chemistry, any marked progress in the physiology of alimentation would not have been possible; the early workers in this particular field were chemists rather than physiologists. The history of physiology during the seventeenth and eighteenth centuries involves the lives and work of numerous investigators, each accomplishing all that was possible considering the advancement of the general scientific knowledge of the time.

Two names of the latter part of the seventeenth and early part of the eighteenth century are prominent as exerting important inflence in the way of solution of the chemical problems of physiology. These were George Ernest Stahl and Hermann Boerhaave. Stahl was born at Anspach in 1660; he studied at Jena, and after graduating became court physician at Weimer, and in 1694 professor of medicine at Halle. He died in 1734 in Berlin, where he moved in 1716 on his appointment as physician to the King of Prussia. Stahl was an accomplished chemist of his day. His views on gastric digestion may be summed up in the following sentence from his work: "Some people suppose that gastric digestion results from the action of particular and specific ferments, and indeed go so far as to regard the stomach as not only the seat but also the origin of a particular ferment, whereas in the whole construction of the stomach nothing particular is observed which would render the elaboration of such a special agent likely." He was a firm believer in the psyche of Aristotle and introduced a principle which he termed anima. He was wholly out of sympathy with those who tried to explain the physical and psychical phenomena of life and mind on chemical and mechanical principles. He could not think of himself as a chemical retort subject to ferments. The soul was to him the living force of the body; "It was susceptible of being played upon by a thousand different influences, such as joy, sorrow and grief, love and friendship, the beautiful, the true, the reverent, the sublime. * * * Can these things be the product of chemical acids and alkalies and the mechanical devices of the mason and builder?" Sir Michael Foster sums up the teaching of Stahl thus: "Learn as much as you can of chemical and physical processes, and in so far as the phenomena of the living body exactly resemble chemical and physical events appearing in non-living bodies, you may explain them by chemical and physical laws. But do not conclude that that which you see taking place in a non-living body will take place in a living body, for the chemical and physical phenomena of the latter are modified by the soul. The events of the body may be rough hewn by chemical and physical forces, but the soul will

shape them to its own end and will do that by its own instrument, motion." Stahl, it will be seen, belonged to the "vitalists," which particular type of physiologist has only within recent years become extinct. His fundamental position was, between living and non-living things there is a great gulf fixed. Living things so long as they are alive are actuated by the sensitive soul; non-living things are not. The rational soul of man governed his whole body. The healing power of nature, vis medicatrix naturae, has been recognized from the most ancient to the present time. Stahl's system was founded upon the supposition that the vis naturae existed entirely in the rational soul. In consequence of Stahl's doctrine, he and his followers proposed the art of curing by expectation, medicina expectans, which practice led to the prescribing of inert remedies, placebos.

Peyer and Brunner—In the catalogue of workers in physiology of the seveneteenth century are the names of Jean Conrad Peyer and Brunner. Peyer was born in Switzerland in 1653. He studied at Basel and Paris and returned to his native town, Schaffhausen, to practise, where he died in 1712. In 1677 he published a brochure in which he described certain new glands scattered over the intestine; these glands are familiar to every student of physiology or histology as "Peyer's patches." He was the first to give a full description of these glnds are familiar to every student of physiology or histology lower part of the small intestine and in the ileum, making a distinction between the single or solitary and the patches of agminated glands. His discovery harmonized with that of Brunner a few years later.

Brunner was born at Dieffenhausen in 1653. He studied at Strassburg and was eventually called to the chair of medicine at Heidelberg, shortly after entering upon his position he published his Dissertatio Inauguralis de Glandulis Duodeni, in which he describes the glands which have since borne his name, Brunner's glands. He attributed to these glands a function similar to the pancreas and spoke of them as a "pancreas secondarium." Brunner had made numerous experiments by removing the pancreas from dogs. He concluded that the animals thus operated suffered in no wise from ill health, consequently the digestive powers of pancreatic juice were practically nothing. These gropings of the seventeenth century are curiously interesting viewed in the light of the twentieth. The work of Peyer and Brunner served to deprive of its glory that of Sylvius and DeGraaf, who had attributed important digestive powers to the pancreatic juice. The attention of physiologists was again centered on the older view that the stomach was the chief seat of digestion.

Mechanical and Chemical Views of Digestion.—Two views concerning gastric digestion contended for first place. One, which may be designated the mechanical, was espoused by Borelli, who was the founder of the so-called Iatromathematical school, which professed to be able to reduce all the motions and activities of nature to mathematical formulae. Borelli's studies were made on the stomachs or gizzards of birds. He pointed out the great grinding or pressing force effected by the muscular coats of the stomach. He compares the action of the fleshy stomach to that of the teeth, and continues: "We have already shown that the absolute force of the muscles which close the human jaw represents a power greater than that of a weight of 1,350 pounds; therefore, the force of the turkey's stomach is not less

than the power of 1,350 pounds." This estimate of the power of the human muscles of mastication, is rather high. Canon in his recent work places the pressure which the molars are capable of exerting at 270 pounds. Borelli admits, however, that certain animals "consume flesh and bone by means of a certain very potent ferment, much in the same way as corrosive liquids dissolve metals." The iatro-physical school eventually went farther than Borelli and denied that chemical action has anything whatsoever to do with digestion, and contended that digestion was mere trituration of the food in the stomach to a creamy substance known as chyle. Bellini, a pupil of Borelli, went farther in the beginning of the eighteenth century and endeavored to explain many functions of the human body from mathematical data. Keill, a member of this cult, calculated from data purely imaginary the power of each organ. According to him the stomach had a force of compression so great that to overcome its own resistance must have meant its own destruction. One iatro-physicist estimated the force of the heart as equal to 180,000 pounds; another placed it at eight ounces. Their calculations were clothed in the imposing nomenclature of the exact sciences. This doctrine is said to have extended to all the universities and medical institutions of Europe.

The iatro-chemical school, or "chemikers" as they were dubbed by Guy Patin, a French physician and wit of the time, sought a solution of all the phenomena of the human body in their flasks and retorts. They maintained that the change in the stomach was chiefly if not wholly a chemical, resulting from the process of fermentation. It was recognized even at this time that the membrane of the stomach was glandular in structure, and yet little importance was attached to the secretion of such membraneous surface.

In 1614 was born Francois de le Boe or Dubois, better known by his Latin name, Sylvius. He is not to be confused with Jacobus Sylvius, the Parisian anatomist, teacher of Vesalius, who lived in the sixteenth century. The latter Sylvius studied at Sedan and at Basel, where in 1637 he took his degree. He became professor of medicine at Leyden, where he exerted a powerful influence until his death in 1672. Sylvius, though distinguished as a physician and physiologist, was essentially a chemist. Through his efforts the curators of the Universtiy of Leyden built for him a "Laboratorium" which, so far as we know, was the first university chemical laboratory. He devoted a large part of his time to a study of salts, which he learned to recognize as resulting from the union of acids with bases. Sylvius looked upon the phenomena of life from a chemical point of view. He was well versed in that part of physiology derived by deductions from anatomy and by experiments on animals. His opinions on the circulation and respiration were orthodox from our modern viewpoint. Harvey's teachings entered largely into his thoughts and it was chiefly through his advocacy that the doctrine of the great discoverer of the circulation of the blood became established in Holland. The contributions which Sylvius made to science were essentially chemical.

Boerhaave—Herman Boerhaave, aready mentioned as a contributor to the chemical knowledge of alimentation, was born in 1668, near Leyden, where he was educated. His early years were largely devoted to the classical and oriental studies. He became Ph. D. in 1690,

having obtained the degree on a thesis, the subject of which was "The Distinction Between Body and Mind." An illness in the shape of an obstinate ulcer of the leg turned his attention to medicine, which he studied along with the ancillary studies, chemistry and botany. He was graduated M. D. in 1693, and eventually gave up the idea of theology for medicine. In 1701 he was appointed to the chair of medicine in the University of Leyden. His great ability as teacher caused students to flock to his lectures. His worth was quickly recognized by the authorities of the university who increased his emolument and endeavored to make his position attractive to prevent him from going elsewhere. Sir Michael Foster says of him: "Much sought after as a physician, acute at the bedside, brilliant as an expositor in the professorial chair, he was also a great teacher in the sense that in his daily intercourse with his pupils he was always ready to lay his mind open before them and to let them share his experience and his thoughts. Russell pays the following tribute to Boerhaave's genius: "Boerhaave was easily the most remarkable physician of his age, a man who, when we contemplate his genius, his condition, the singular variety of his talent, his unfeigned piety, his spotless character and the impress he left not only on contemporary practice, but on that of succeeding generations, stands forth as one of the brightest names on the pages of medical history, and may be granted as an example not only to physicians but to mankind." Boerhaave was a scholar and scientific thinker, too broad to be the slave of one idea. He was eclectic in the true sense of the term, though he never allied himself with the medical sect which goes by that name. He had a mind open to truth wherever it might be sought. He made use of anatomy, physics and chemistry, but never allowed one to exclude the other. He made each subservient to the elucidation of physiology.

Boerhaave was not an extreme advocate of either mechanical or the chemical fermentative school; he recognized that digestion is in part a solution of some of the constituents of food by means of various juices, which he, however, regarded not of the nature of fermentation. He denied, however, the acidity of the gastric juice. Colored vegetable juices were at the time coming to be used as we now use litmus paper, in reaction tests. Boerhaave regarded the solution by means of juices only as part of the digestive process; the remaining process he held consisted of trituration in the stomach, by which process the nutritive parts of food were expressed. His views were dominant the early part of the eighteenth century.

An Epochal Year, 1757—The years 1757 was the dividing line between modern physiology and all that had gone before. It was the date of the publication of the first volume of Haller's Elementa Physiologia, the eighth volume of which appeared in 1765. Albrecht von Haller was born at Berne, Switzerland, in 1708. The story is told of his early precosity, when at the age of four he is said to have expounded the Bible to his father's servants. Before he was ten, he wrote in Latin verse a satire on his tutor. Haller's attention had been directed to medicine after his father's death in 1721, while residing in the house of a physician in Biel, and in his sixteenth year he entered the University of Tubingen. Dissatisfied with his progress there, he went to Leyden ,where Boerhaave was at the height of his fame. He graduated in 1727, and turned his attention to botany, publishing a

great work on the flora of Switzerland. He returned to Berne and began the practice of medicine in 1729. In 1736 he was appointed professor of medicine, anatomy and botany in the newly founded university of Gottingen, a position which he had held for 17 years. During this time he carried on original investigation in botany and physiology. His researches on the formation of bone, the mechanics of respiration, and the development of the embryo are of the highest importance. Regarding Haller as an expositor in physiology, Foster writes: "When we turn from the preceding writers on physiology and open the pages of Haller's Elementa, we feel that we pass into modern times. Save for the strangeness of most of the nomenclature, and for no small differences in all that relates to the chemical changes of the body, we seem to be reading a modern text-book of the most exhaustive kind." His chief service, however, was the careful arranging and digesting of the theories and facts of physiology up to this time. From his time physiology became an independent branch of science, to be pursued for itself rather than as an adjunct to medicine. Regarding Haller's method of exposition, the same writer goes on to say that "In dealing with each subdivision of physiology, Haller carefully describes the anatomical basis, including the data of minute structure, physical properties and chemical composition, so far as these were then known. He then states the observations that have been made, and in respect to each question, as it arises, explains the several views which have been put forward, giving minute and full references to all the authors quoted, and he finally delivers a reasoned critical judgment expounding the conclusions which may be arrived at, but not omitting to state plainly when necessary the limitations which the lack of adequate evidence places on forming a decided judgment. He carefully recounts and as carefully criticizes all the knowledge that can be gleaned about any question. If he feels unable to come to a decided conclusion he candidly says so."

But we are most concerned at present with what Haller has to say on digestion. He considered saliva neutral in reaction and possessing no digestive properties further than the softening of food as an aid to deglutition. He recognized the importance of the glandular coat of the stomach, which glands he concluded furnished mucous only, the true gastric juice being derived from the arteries. He also concluded that pure gastric juice was neither acid nor alkaline and refused to regard it as some of his predecessors had done, as a ferment. The acidity he considered a token of the degeneration of the digested food. Trituration he regards as a useful aid to digestion, especially where hard grains form part of the food as in birds; but it was only an aid.

Bile, he claimed, was not a mere excrement; it was secreted by the liver and stored for a time in the gall bladder, where it underwent slight change. Bile is a viscid fluid, bitter but neither acid nor alkaline. It has the power of dissolving fats, and so acts on a mixture of oil and water as to form an emulsion. Haller considered the importance of the pancreas due to the fact that its ducts opened into the intestine in common with the bile duct; that its fluid softened and diluted the bile, thus enabling it to mix more satisfactorly with the food. He concluded by prophesying that there may be other functions of pancreatic juice not well known to the physiologists of his day.

Reaumur and His Methods. Rene Antoine Ferchault de Reaumur, a Frenchman born in 1683, and described as one of the most notable men of science of the eighteenth century, is, in chronological sequence next most important contributor to the physiology of the alimentary tract. His name is already familiar to most of us as the inventor of the Reaumur thermometer. His studies on the gastric juice at this time are all-important, inasmuch as his methods are unique. Reaumur had in his possession a kite and took advantage of the habit of the bird of ejecting from its stomach things swallowed which it could not digest. The kite was fed pieces of meat secured in metal tubes. It was found that meat when ejected had no odor of putrification. Experiments were made with small pieces of bone, which were completely dissolved when ejected and swallowed by the kite several times. On vegetable grains and flour, the fluid of the kite's stomach had apparently little effect. The tubes were filled with small pieces of sponge, which, when ejected, were squeezed out, thus enabling the investigator to procure pure gastric juice and to study it in vitro. He proved that digestion was not putrifaction but something really opposed to that process. While Reaumur's experiments left much to be ascertained about gastric digestion, he at least favored the solvent power of the succus gatricus, by the employment of a wholly new method.

Experiments with Gastric Juice. We must look to Italy for the next contributor to our knowledge of digestion. Parenthetically, it is of interest to note that the idea of specializing, if it had taken root at all at this early time, was not markedly apparent. The worker in the physiology of digestion was equally prominent in almost every other department of physiological research. Lazzaro Spallanzani (1729-1799) was one of the most eminent men of his time. Educated for the church, he was usually known as Abbe Spallanzani. His life was devoted to experiments, researches and teaching. He was professor at Bologna, and afterwards at Pavia. We find him first experimenting with germ life, with results that disprove the doctrine of spontaneous generation. His researches in other fields showed that he had conceived the truly scientific method.

Spallanzani took up Reaumur's methods and most of his results were achieved by them. Aided by improvements in chemistry, he was able to make marked advance over his predecessors. His experiments were made on all kinds of animals, fishes, frogs, serpents, birds, sheep oxen, horses, cats and dogs, and lastly upon himself. Besides hollow tubes, he used hollow spheres, freely perforated, into which were placed meat and bread, bone or grains of wheat, and the results of digestion were studied when these were ejected or procured by opening the animal's stomach. He also attached pieces of meat to threads, which he would draw from the animal's stomach at fixed intervals. He experimented upon himself by swallowing linen bags containing bread, meat and similar articles, examining the contents after they had been voided per anum. He procured gastric juice from himself by producing vomiting on an empty stomach. He repeatedly tested the action of gastric juice in vitro, keeping the tubes a uniform temperature by retaining them in his arm pit, using the same food covered by water as a control. He found that gastric juice acted more readily upon finely divided parts of food such as crushed grain

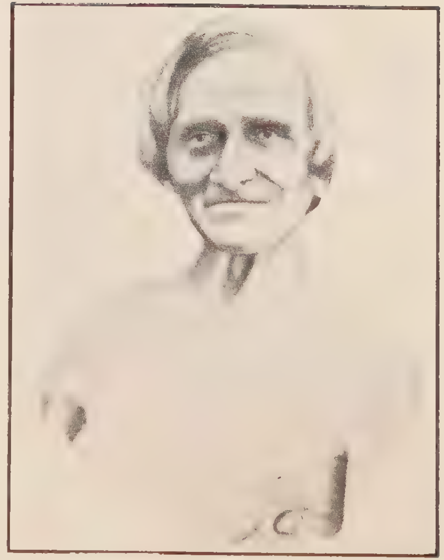
or bone which proved trituration only a preparation for solution, and that it was no further a part of the digestive process.

He found that the gastric juice dissolved the food of animals into a pultaceous mass or chyme. He observed that heat favored solution and that in warm-blooded animals certain high temperature was necessary for the chymification of foods. In Spallanzani's time putrifaction was considered a form of fermentation. "There are three kinds of fermentation, the vinous, the acetous, and the putrid." The action of gastric juice was not putrid; in fact, it tended to arrest putrefaction. Spallanzani was inclined to believe that the action of the gastric juice was neither vinous nor acetous. Regarding the reaction of gastric juice his conclusion was that it was neutral. He believed that the acidity was due to an abnormality of the stomach contents, inasmuch as the regurgitation of sour material from the stomach occurred only when something had gone wrong. Spallanzani's failure to recognize the acidity of the gastric juice limited his further investigations. He could only conclude that the action of the gastric juice was not fermentation, as fermentation was understood at the time.

It is interesting to note that the results of Reaumur and Spallanzani were confirmed by Stevens of Edinburgh, who likewise employed Reaumur's methods of investigation. Stevens experimented on a "man of weak understanding who gained a miserable livelihood by swallowing stones for the amusement of the common people." The man was made to swallow perforated silver spheres containing animal and vegetable food, raw and cooked, which were examined when voided some 48 hours later. Similar experiments were made on dogs, the contents of the hollow spheres examined after opening the animal's stomach. Stevens concluded that digestion is not the effect of heat, trituration, putrification or fermentation alone, but of a powerful solvent secreted by the glandular coat of the stomach.

Summary: Summing up the progress made in the physiology of digestion during the seventeenth and eighteenth centuries, probably no one is more entitled to an audience than Sir Michael Foster; "During the two centuries the seventeenth and the eighteenth, physiological inquiries, swayed now in one direction by views of chemical fermentation or effervescence, now in another direction by views of mechanical trituration, had come in the end to the conclusion that digestion was in the main a process of solution of a peculiar character, begun and chiefly carried out in the stomach, though assisted by minor subsequent changes taking place along the intestines. They who were under the influence of vitalistic doctrines, and these were perhaps the more numerous, held the change to be the commencement of, to be the first step in the conversion of food into living flesh and blood, and spoke of it as a change differing from ordinary chemical change, without being able to define the exact characters. It was left to the nineteenth century to throw new light on the nature of the gastric changes and at the same time to show that what took place in the stomach was not the whole digestion, but only the first of a series of profound changes taking place along nearly the whole length of the alimentary canal."

DR. WILLIAM BEAUMONT.



ALEXIS ST. MARTIN.
Showing Gastric Fistula

Reproduced from Dr. Myer's Life and Letters of William Beaumont.

CHAPTER III.

PHYSIOLOGY OF DIGESTION—WILLIAM BEAUMONT

We have traced the development of the physiology of alimentation from its crude beginnings, when debate waged as to whether digestion consisted of mechanical trituration or whether it consisted wholly of a fermentative process, to the time when some real light began to be shed upon the subject by experiment with the gastric secretion itself. No contribution to the subject of gastric digestion has been of such moment as the work of William Beaumont on the gastric secretion of the French Canadian, Alexis St. Martin. The story of Beaumont's life and the circumstances surrounding his work constitute one of the most fascinating chapters in the history of American Medicine.

As physicians, we have become familiar with the names of Beaumont and St. Martin early in our student career. They have become inseparably associated with the study of gastric juice and its functions. Standard works on physiology introduce the chapter on digestion with such sentences as: "Gastric fistulae have been made in human beings, either by accidental injury or by surgical operation. The most celebrated case is that of Alexis St. Martin, a young Canadian who received a musket wound in the abdomen in 1822. Observations made upon him by Dr. Beaumont formed the starting point of our correct knowledge of the physiology of the stomach and its secretions."* "The first fistula of a digestive gland to be the subject of a thoroughly scientific investigation was one resulting from a gun shot wound in the stomach of a Canadian hunter. As the consequence of his accident, the hunter had all the rest of his life a stomach fistula opening at the upper part of the abdomen, through which the interior of the stomach could be observed and gastric juice could be obtained. Beaumont collected a large number of important facts (1825-1833) concerning the digestive process of the stomach and concerning the movements of that organ." "Beaumont's study of St. Martin's stomach showed that in acute catarrh the mucous membrane is reddened and swollen, less gastric juice is secreted, and mucous covers the surface." Instances might be quoted almost ad infinitum of references in medical literature to Beaumont's classic study of gastric digestion.

Beaumont; His Early Life: William Beaumont, the third child of Samuel Beaumont, who had seen active service during Revolution days prior to the Declaration of Independence, was born November 21st, 1785. There was nothing unusual in his childhood and youth. As he grew to manhood his sympathies and political leanings were in accord with those of his father, who was a staunch Democrat and patriot. While no church record assures us that he was of the faith of his parents, Congregationalist, his biographer asserts that when the roll of the drum announced the approaching hour of worship he was among those who slowly wended their way over the hills on foot or on

*Halliburton's Handbook of Physiology; Tigerstedt's Physiology; Osler's Practice.

horseback to the old meeting house. Beaumont was blessed with such rigorous parental discipline in youth that he explained his lapses in church attendance in after life by the statement that during his youth he had made up for a lifetime of church attendance. Further than that he was a courageous and fearless boy, little is known of his early life. It is said that he developed deafness, which became more marked as he grew older, from standing near a cannon which was being fired, simply to outwit playmates of his own age.

The beginning of last century found Beaumont a boy of fifteen years. It was twenty-four years since the first birthday of the American Nation. Beaumont's youth was contemporaneous with one of the most stirring epochs in world history. The United States was beginning to assume an important place among the nations of the world. Beaumont left home during the winter of 1806-7 with, we are told, an outfit consisting of a horse and cutter, a barrel of cider, and a hundred dollars of hard earned money. He traveled Northward, reaching in the spring of 1807 the little village of Champlain, New York. He was very favorably impressed with his surroundings and with the people, who were mostly farmers, and whom he characterized as "peaceful and industrious in general." Here he established his "Lares and Penates" and followed the career of schoolmaster. Coming from one of the best New England schools his services were much in demand. While teaching school and during the vacation he found time to devote to medical studies. He had supplied himself with books borrowed from Dr. Pomeroy of Burlington, Vt., which town was on his itinerary to Champlain. Beaumont, as many since his day have done, made teaching a stepping stone to the profession of medicine, and an excellent experience it is for the aspiring savant. In 1810 he was apprenticed to Dr. Chandler of St. Albans, Vt. He seems to have exhibited a wise choice in the matter of preceptor. "Living under the same roof," writes Dr. Myer, describing the medical education of the times, "as was customary in the days of medical apprenticeship, the preceptor could look after both the mind and morals of his pupils. The fledgeling in return for the instruction received at the hands of his master, not only compensated him for his trouble, but performed many of the menial offices of a servant about the house and office. It was he who prepared the powders, mixed the concoctions, made pills, swept the office, kept the bottles clean, assisted in operations and often through main force supplied the place of the anæsthetic of today, in the amputation of limbs and other surgical procedures. He rode about with the doctor from house to house, profiting by his personal experience and jotting down on the pages of his note book and on the tablets of his memory the words of wisdom that fell from his master's lips. * * * He was taught the symptoms of disease, the crude methods of diagnosis, the art of prescription writing and the process of cupping and bleeding, considered so effective in its day."*

Medical books were rare and expensive, and fortunate was the student who had access to them. Dissections were rarely performed, owing largely to the fact of inadequate means of preserving cadavers. Such were young Beaumont's opportunities.

Beaumont spent the two years of his apprenticeship with diligence, studying the masters. He dissected whenever an opportunity

*Life and letters of Dr. William Beaumont, by Jesse S. Myer.

afforded, and never lost an opportunity to perform post-mortems. A perusal of his case histories shows what a careful observer he was—a qualification of the first importance in a physician. His diploma or license to practice was granted the second Tuesday of June, 1812, by the third Medical Society of the state of Vermont. It reads:

> By the Third Medical Society of the State of Vermont as by law established, William Beaumont having presented himself for examination on the anatomy of the human body, and the theory and practice of physic and surgery, and being approved by our censors, the society willingly recommends him to the world as a judicious and safe practitioner in the different avocations of the medical profession. In testimony whereof we have hereunto prefixed the signature of our president and the seal of the society at the Medical Hall in Burlington on the second Tuesday of June, A. D. 1812.
>
> CASSIUS F. POMEROY, Secretary. JOHN POMERY, President

Assistant Army Surgeon: In September the same year Beaumont joined the army at Plattsburgh, as assistant surgeon under General Dearborn. His old preceptor Dr. Chandler had unsuccessfully tried to dissuade him from the army service, advising him to settle down to private practice. Apparently there is a destiny which shapes our ends. Had he followed the advice of his old master, he would in all probability have been among the thousands of good men who have lived their lives through, leaving the world a little better than they found it, and passed into the silent land, pass and leave no sign to indicate that they have been. But Beaumont followed his own bent and it was while acting as army surgeon that he made the momentous discoveries which have placed him among the epoch-makers of medical history. It is significant to note that more than one army surgeon has performed service of an extraordinary nature to medical science. Fom the times when Machaon and Podilirius rendered aid to the Greek hosts at ancient Troy to the days of Ambrose Pare, the army surgeon has been identified with medical progress. A name honored within recent years in the French service is that of Laveran, who during his tour of duty in Algeria did a work in connection with malaria which made possible the work of Sir Ronald Ross, of the Indian medical service, and his associates of more recent times. The spectacle of the Panama Canal and its construction were made possible by the United States Army medical service. In the British Army medical service are such names as Sir David Bruce, whose investigations led to the extermination of Malta fever.

Beaumont's Diary: Beaumont left a diary which is an interesting description by one on the firing line, of the stormy times of 1812. This graphic account of events of the war by an eye-witness is reproduced in Dr. Meyer's book. Beaumont was present August, 1814, at the battle of Plattsburgh, where General Macomb defeated the British under General Provost. The Treaty of Ghent ratified in February, 1815, closed the war. Soon after the close of the war of 1812 Beaumont tendered his resignation and in partnership with a Dr. Senter opened a store in the town of Plattsburgh, which store contained "a general assortment of drugs, medicines, groceries, dye woods, etc., of the first quality and choicest selection which they calculate to sell on liberal terms for cash or approved credit." So runs the advertisement

in the local newspaper. In the footnote of the advertisement it is stated that "Medicines will be put up with accuracy and care." In December of 1816 Beaumont sold out and afterwards confined himself entirely to the practice of his profession. He was commissioned by President Monroe in 1820 and re-entered the military service, when he was ordered to Fort Mackinac on the Northwestern frontier. He describes his journey in detail in his diary. His course lay along the southern shore of Lake Erie to the Detroit river, where he passed Fort Malden, near the Canadian town of Amherstburg, opposite Bois Blanc island. He describes the fort at Detroit as a "regular work of an oblong figure covering about an acre of graceful slopes." The parapets are about 20 ft. in height, built of earth and sodded, with four bastions. The whole surrounded with palisades, a deep ditch and glacis. It stands immediately back of the town and has strength to withstand a siege. The Detroit postoffice, corner of Fort and Shelby streets, stands upon the ground at one time occupied by the above mentioned fortification. A bronze tablet at the south entrance of the postoffice gives in brief the vicissitudes of the old fort.

He speaks of crossing over to Sandwich, then a small French village. There is no mention of the route again until he reaches Fort Michilimackinac, which is described as handsomely situated on the southeast side of the island of this name, on a bluff rising from 100 to 200 feet from the water, almost perpendicular in many places, extending about half way around the island. The word "Michilimackinac" means "turtle" from the resemblance of Mackinac island on being approached.

The following entries in his diary throw considerable light on the character of the man himself.

Sept. 9, 1820. Commenced a diary of conduct on Dr. Franklin's plan, for obtaining moral perfection." (Benjamin Franklin appears to have been a favorite with Beaumont, for he elsewhere quotes him at length.) "Reading Shakespeare today I judged the following extracts worthy of copying; 'Love all, trust few, do wrong to none; be able for thine enemy rather in power than use; and keep thy friend under thy life's key; be checked for silence, but more taxed for speech.

"10th. Rose at six o'clock. Visited my patients in village and discharged garrison duty before 9 a. m. Settled my hospital account, perused scriptures and Pope's Essay on Man till evening."

Beaumont's diary is an interesting narrative of the times, written by a keen and practical observer.

The Psychological Moment: Late in the spring of 1822 occurred the event which made the name of William Beaumont famous in the annals of medicine. Indians and voyageurs had returned to Mackinac with the results of the winter's hunting. A strange medley of humanity had gathered at the Amercan Fur Company's trading post. On the 6th of June a gun was accidentally discharged, its contents entering the upper abdomen of a young voyageur, leaving a cavity which would have admitted a man's fist. According to an eye-witness Alexis St. Martin, for that was his name, fell, as every one supposed, dead. Dr. Beaumont, surgeon of the fort, was called, and arrived shortly after the accident. Shot and pieces of clothing were extracted and the wound dressed. The surgeon then left with the re-

mark that the man couldn't live 36 hours. The doctor called again in the course of two or three hours and found the patient better than he had anticipated. The patient was removed to the fort hospital where he eventually recovered, leaving, however, a permanent gastric fistula. Beaumont's own account of the accident is told in the introduction to his work on "Experiments and Observations of Gastric Juice."

"Alexis St. Martin, who is the subject of these experiments, was a Canadian of French descent at the above mentioned time (1822) about 18 years of age, of good constitution, robust and healthy. He had been engaged in the service of the American Fur Company as a voyager and was accidentally wounded by the discharge of his musket on the 6th of June; the charge, consisting of powder and duck-shot, was received in the left side of the youth, he being at a distance of not more than one yard from the muzzle of the gun. The contents entered posteriorly and in an oblique direction, forward and inward, literally blowing off integuments and muscles of the size of a man's hand, fracturing and carrying away the anterior half of the sixth rib, lacerating the lower portion of the left lung, the diaphragm and perforating the stomach. The whole mass of materials forced from the musket, together with fragments of clothing and pieces of fractured ribs, were driven into the muscles and cavity of the chest. I saw him in 25 or 30 minutes after the accident occurred, and on examination found a portion of the lung as large as a turkey's egg protruding through the external wound, lacerated and burned; and immediately below this another protrusion which, on further examination, proved to be a portion of the stomach lacerated through all its coats and pouring out the food he had taken for his breakfast through an orifice large enough to admit the forefinger."

Beaumont's hospital and bedside notes give a complete history of the case.

Being destitute and without friends or relatives, Alexis St. Martin became a pauper on the town of Mackinac. It was at last decided to ship him to his native town, Montreal, nearly one thousand miles away. Beaumont, however, rescued him from misery and inevitable death by taking him into his own family. "During this time, says his benefactor, I nursed him, fed him, clothed him, lodged him and furnished him with every comfort and dressed his wounds daily and for the most part twice a day." It should be realized that Beaumont endeavored to close the wound; that when all other means failed he suggested incising the edges of the wound and, "bringing them together by sutures, an operation to which the patient would not submit."

Not until three years after the accident did the idea of performing a number of experiments appear to occur to the mind of Beaumont. In 1825 he began to realize the importance of this case which had fallen to his care, when it occurred to him what a great service to humanity might result from this accident. About this time Beaumont describes the situation as follows:

'He (St. Martin) will drink a quart of water or eat a dish of soup and then by removing the dressings I frequently find the stomach inverted to the size and about the shape of a half-blown rose, yet he complains of no pain, and it will return itself or is easily reduced by gentle pressure. When he lies on the opposite side I can look directly into the cavity of the stomach and almost see the processes of digestion. I have frequently suspended flesh, raw and wasted, and other substances into the perforation to ascertain the length of time re-

quired to digest each, and at one time used a tent of raw beef instead of lint to stop the orifice, and found that in less than five hours it was completely digested off as smooth and as even as if it had been cut with a knife."

Then his resolve to make use of the case as a means of studying gastric digestion takes shape as follows:

"This case affords an excellent opportunity for experimenting on the gastric fluid and process of digestion. It would give no pain nor cause the least uneasiness to extract a gill of fluid every two or three days for it frequently flows out spontaneously in considerable quantities. Various kinds of digestible substances might be introduced into the stomach and then easily examined during the whole process of digestion. I may, therefore, be able hereafter to give some interesting experiments on these subjects."

Recognition of Michigan Medical Society: The Medical Society of the territory of Michigan was the first body to recognize the work of William Beaumont. The following letter dated from Detroit announced his election as an honorary member of the Michigan Territorial Medical Society.

"Dr. William Beaumont, United States Army, Michilimackinac.

Detroit, March 3, 1825.

"Sir:—It is with much pleasure that I transmit to you as an extract from the minutes of the medical society of this territory at a meeting held at the home of Capt. Woodworth in the City of Detroit on Monday, 7th ultimo; Dr. William Beaumont, of the United States Army, duly proposed by Dr. Pitcher and unanimously elected by ballot an honorary member of this society.'

"Whereupon it was ordered that the secretary be directed to inform Dr. Beaumont of his election as aforesaid.

"I remain, sir, with much respect,

"Your most obedient servant,

"JOHN S. WHITING,

"Secretary of the Medical Society of the Territory of Michigan."

The first experiments were carried on at Mackinac and were continued at Fort Niagara, to which place Beaumont was removed. While on a visit to Burlington, Vt., as one of his master's household, Alexis, whose interest in science had long ago reached the vanishing point, ran away and was lost to his benefactor for some time. This ungrateful act on the part of the French-Canadian proved a sore disappointment to our "Backwoods physiologist." His experiments up to this time were to estimate the length of time required for the digestion of certain kinds of food, which were suspended in the stomach by means of silk threads and withdrawn from time to time to note the changes in the substances. He found that food would digest more quickly in the stomach than when mixed with gastric juice in vitro.

Four years after St. Martin's unceremonious departure, Beaumont got in communication with him. In the meantime Alexis had married and became the father of two children. The doctor took him, his wife and two children into his own home, where Alexis did duty as a common servant when not employed for purposes of experimentation. Beaumont's laboratory equipment consisted of a thermometer, a few open mouthed vials and a sand bag. His observations

were made with a true spirit of inquiry and with no particular hypothesis to support. Fifty-six experiments were made between Dec. 6th, 1829, and April 9th, 1831. Alexis, with his wife and family, were permitted to return home to Quebec on the promise to appear when again wanted. Beaumont had felt that he had accomplished about all he was able in his researches on gastric digestion, and he longed to go to Europe a year and take St. Martin with him, that the work might be pursued farther by more competent physiologic chemists. The brevity of his furlough precluded the idea of going abroad and instead he remained in Washington with Alexis where he found his surroundings very congenial. Access to the works of European physiologists in the library and recognition from many of the prominent men at the capital made his sojourn pleasant.

Between Dec. 1st., 1832 and March 1st, 1833, we find recorded 116 experiments, some in confirmation of what had been done before. He tested the temperature of the stomach when full, when fasting, when exercising, when resting, also the length of time required to digest various food substances. He also experimented to disprove the old theory of maceration or mechanical trituration.

Seeks Assistance of Two Leading Scientists: In 1833 Beaumont sought the assistance of two of the leading scientific men of the United States, Robley Dunglinson, professor of physiology, University of Virginia, and Benjamin Silliman, professor of chemistry at Yale. Thanks to Beaumont's painstaking and methodical nature, the correspondence between the two and himself had been carefully preserved, and it constitutes an excellent account of the physiology of the period. A sample of gastric juice from St. Martin's stomach was sent Dunglinson for analysis with the request to convey to the giver the results and to refrain from publishing anything that would anticipate the labors of Beaumont himself. He is assured that the professor has but one desire in the prosecution of his profession; by teaching and practice to benefit his fellow men, which could always be done with due credit without forestalling his coadjutors in the field of science, or arrogating to himself merit to which he might be but secondarily entitled. Dunglinson found the sample of gastric juice to contain "free muriatic and acetic acid and phosphates and murates with bases of potassa, soda, magnesia and lime and animal matter soluble in cold but not in hot water."

Professor Silliman, to whom a bottle of gastric juice was also submitted, suggested that a sample be sent to Professor Berzelius, of Stockholm, Sweden, "as the man of all others best qualified to investigate a subject of such deep interest to mankind." Accordingly a bottle of the digestive fluid was packed for shipment. Beaumont's disappointment may be imagined when it was known that the parcel was delayed over two and a half months. This he learned about the time he was patiently awaiting the results of the Swedish professor's investigations. In the meantime Beaumont had received a letter from Professor Silliman enclosing an abstract of a portion of a system of chemistry by Berzelius, important as presenting a clear idea of the knowledge of the physiology of digestion at that time (1833). The communication states, among other things, that Prout, Tiedeman and Gmelin gave the best notions on the subject of gastric juice and ex-

plained the contradictory statements of other authors; at one time it was said to be very fluid clear and neutral in reaction; then alkaline, then acid. Prout in 1824 declared the gastric juice to contain free hydrochloric or muriatic acid, the result of an experiment made on the contents of the stomach of an animal killed soon after eating. Gmelin and Tiedeman also established the presence of free hydrochloric acid. The fluid of the empty stomach was found to be slightly acid, sometimes neutral and the acidity was in proportion to the quantity, becoming very acid when food had been swallowed. According to Gmelin and Tiedeman, the salts of gastric juice were principally sodium chloride and potassium chloride in small quantities, hydrochlorate of ammonia and a little sulphate of potassium. The communication concludes with the assertion that "no organ for the special secretion of the gastric juice has yet been discovered."

Berzelius' Reply Disappointing: Through Professor Silliman, Beaumont eventually heard from Berzelius, whose letter was dated July, 1834. The communication upon which such great expectations were placed was wholly disappointing. It was in the main an apology for the writer's inability to work with the gastric fluid with prospects of results of any value, owing to the time which had elapsed since its secretion and its arrival at his laboratory, to the possible alteration on account of summer heat, and to the inadequate quantity received.

Nothing but the utmost zeal and love for the work could account for the persistence with which Beaumont pursued his researches. He felt not only the handicap of inadequate resources and facilities for experimentation, but St. Martin was a source of canstant annoyance to him. He would leave his master and benefactor, often absent for several years, when by overtures in the shape of money he would be prevailed upon to return and furnish the precious fluid for his master's investigation. Beaumont's lot was cast at a time when it was difficult, almost impossible, to obtain government grants for the promotion of education. His work, therefore, has been accomplished almost entirely at his own expense.

Attains Fame Through His Stomach: St. Martin lived the life of the French Canadian habitant mostly in poverty, though physically he was, the larger part of his life, in good condition. Nine years after his notable accident, we are told, he took his family in an open canoe via the Mississippi, passing St. Louis, ascended the Ohio River, then crossed the state of Ohio to the lakes and descended the Erie and Ontario and the River St. Lawrence to Montreal, the trip consuming the interval from March to June. He was able to engage in manual labor requiring considerable strength and endurance. Perhaps his extreme poverty is due to lack of thrift and to intemperance, for we are told that he indulged immoderately in the "glass that cheers."

The longevity of the habitant is evidenced in St. Martin, for he lived twenty-eight years after the death of Beaumont. St. Martin's death occurred in his eighty-third year. Sir William Osler, at the time, (1880) a resident of Montreal, reading of his death, wrote the local physician and parish priest urging them to secure for him the privilege of an autopsy, and at the same time offering a goodly sum for the stomach, which he intended to place in the Army Medical Museum at Washington, but his entreaties were of no avail, the

body was interred eight feet below the surface of the ground, after being detained at home much longer than the usual period, so that decomposition setting in, might baffle the doctors, and prevent any attempts at resurrection.

Beaumont Resigned From Army: William Beaumont resigned his position as army surgeon in 1839. He continued, however, to attend the families of the officers at St. Louis, where he made his home. Owing to the distance from St. Louis of his successor, who was stationed ten miles away, he presented an account to the War Department for professional services covering a period of a few months, which services he conceded "irregular and informal," but "correct and just." On receipt of his account the surgeon-general threatened either to ignore the bill or to deduct the amount from the salary of Beaumont's successor. The manner in which Beaumont received the threat showed the independent nature of the man. He declared the surgeon-general's view at "absurd opinion, contracted view, narrow-minded vindictive spirit and petty tyrannical disposition," of the "weak, waspish and wilful head of a medical department," and congratulated himself over having the "privilege of detesting a man, the motives and the mind from which such egregius folly, parsimony and injustice could emanate and be promulgated." The Surgeon-General was, however, unyielding, and Beaumont's claims were unrecognized.

Though severed from the War Department, he still had a very lucrative practice, and what is above any monetary consideration, devoted friends, and was very happy in his domestic relations. The following paragraph quoted in Dr. Myer's Life and Letters of Beaumont gives a splendid estimate of his character:

"Dr. Beaumont possessed great firmness and determination of purpose. Difficulties which would have discouraged most men, he never allowed to turn him from his course. These he did not attempt to evade but to meet and overcome. He possessed more than any man I ever knew, a knowledge almost intuitive of human character. You might have introduced him to 20 different persons in a day, all strangers to him, and he would have given you an accurate estimate of the character of each, his peculiar traits, disposition, etc. He was gifted with strong natural powers which, working upon an extensive experience in life, resulted in a species of natural sagacity, which I suppose was something peculiar to him not to be attained by any course of study. His temperament was ardent but never got the better of his instructed and disciplined judgment, and whenever or however employed, he always adopted the most judicious means of obtaining ends that were always honored. In the sick room he was a model of patience and kindness; his intuitive perceptions guiding a pure benevolence never failed to inspire confidence. Thus, he belonged to that class of physicians whose very presence affords nature a sensible relief."

He died on April 25th, 1853. His death was considered the result of injuries he received by slipping on icy steps while making a professional visit. What a satisfaction such a life must be, and the resignation with which one might approach the infirmities of old age and one's final destiny. And indeed a few months before the end he breathed forth this beautifuly symphony:

"Myself and wife, not unlike John Anderson my Jo, have climbed the hill o' life togither, and mony a canty day we've had wi' ane anither. But now we maun totter down life's ebbing wane in peaceful quiet ease and compitence, with just so much selfishness and social sympathy as to be satisfied with ourselves, our children and friends, caring little for the formalities, follies and fashions of the present age. * * * Come when it may, we only ask God's blessing on our frosted brows and hand in hand we will go to sleep together."

DR. BEAUMONT'S BOOK.

I am fortunate in having before me an original copy of Dr. Beaumont's work. The title page bears the following description: "Experiments and Observations on the Gastric Juice and the Physiology of Digestion, by William Beaumont, M. D., Surgeon in the United States Army. Plattsburg. Printed by F. P. Allen, 1833." The volume is dedicated to Joseph Lovell, M. D., Surgeon General of the United States Army. The work comprises 280 pages, 122 of which deal with "Preliminary Remarks on the Physiology of Digestion." The remainder deals with Experiments and Observations on the Stomach of Alexis St. Martin. The first part is divided into seven sections, as follows: 1st, Of Ailment; Section two of Hunger and Thirst; Section three of Satisfaction and Satiety; Section four of Mastication, Insalivation and Deglutition; Section five of Digestion by Gastric Juice; Section six of the Appearance of the Villous Coat and of Motions of the Stomach; Section seven of Chylification and Uses of the Bile and Pancreatic Juice. There are three illustrations, consisting of crude wood cuts of the gastric fistulæ. The typographical appearance of the work should be considered creditable considering the printing art at the time. The conclusion of the second part of the work contains 51 inferences made from the foregoing experiments and observations. Of these I shall quote a few:

That digestion is facilitated by minuteness of division and tenderness of fibre and retarded by the opposite qualities.

That the quantity of food generally taken is more than the wants of the system require, and that excess, if persevered in, generally produces not only functional aberration but disease of the coats of the stomach.

That bulk as well as nutriment is necessary to the articles of diet.

That oily food is difficult of digestion, though it contains a large proportion of the nutrient principles

That stimulating condiments are injurious to the healthy stomach.

That the use of ardent spirits always produces disease of the stomach if persevered in.

That the agent of chymification is the gastric juice, which acts as a solvent of food and alters its properties.

That the action of gastric juice is facilitated by the warmth and motions of the stomach.

That it coagulates albumin and afterwards dissolves the coagulum.
ciples.

That the gastric juice is secreted from vessels distinct from the mucous follicles.

That bile is not ordinarily found in the stomach and is not commonly necessary for the digestion of food, but assists in the digestion of oily foods.

That the inner coat of the stomach is of pale pink color, varying in its hues according to its full or empty state.

That the motions of the stomach produce a constant churning of its contents and admixture of the food and gastric juice.

That these motions are in two directions, transverse and longitudinal.

Beaumont failed, however, to ascribe any digestive function to the saliva. He maintained that food finely divided placed directly into the stomach was as completely digested as that which entered by the oesophageal route.

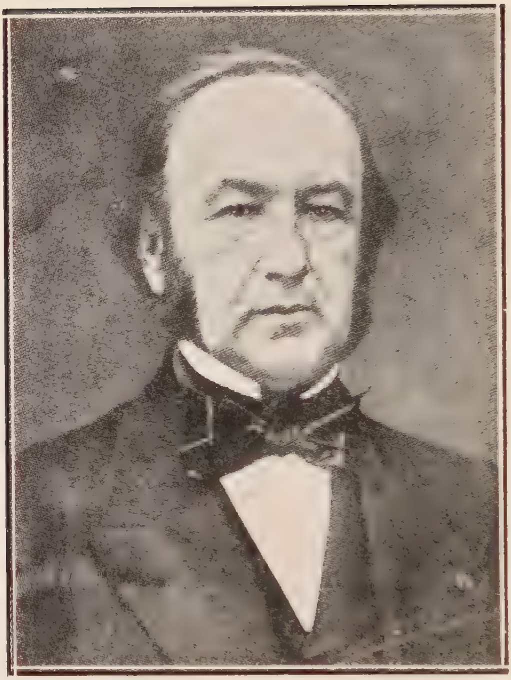
When he began his work the status of the physiology of digestion had been very well described by William Hunter; "some physiologists will have it that the stomach is a mill; others that it is a fermenting vat; other again that it is a stew pan; but in my view of the matter it is neither a mill, a fermenting vat nor a stew pan, but a stomach, gentlemen, a stomach." When William Beaumont completed his labors there was a marked advance in knowledge of the digestive process. Among the most important results of his work was his complete and accurate description of the gastric juice, which has been quoted in so many text books since his day.

"Pure gastric juice when taken directly out of the stomach of a healthy adult, unmixed with any other fluid, save a portion of the mucus of the stomach with which it is most commonly, perhaps always combined, is a clear, transparent fluid; inodorous; a little saltish, and perceptibly acid. Its taste, when applied to the tongue, is similar to mucilaginous water, slightly acidulated with muriatic acid. It is readily diffusible in water, wine or spirits; slightly effervescent with alkalies, and is an effectual solvent of the materia alimentaria; it possesses the property of coagulating albumin in an imminent degree; it is a powerful antiseptic, checking the putrefaction in meat; and effectually restorative of healthy action when applied to old foetid sores and foul ulcerating surfaces."

His work confirmed the observation of Prout, that the acid contents of the gastric secretion was hydrochloric. He recognized the fact that the elements of the gastric juice and the mucus of the stomach were a separate secretion. He established by direct observation the marked influence of mental states on the secretion of gastric juice and on digestion. His was the first comprehensive and thorough study of the motions of the stomach; and to quote Osler: "His study of the digestibility of different articles of diet in the stomach remains today one of the most important contributions ever made to practical dietetics."

A German edition of the work was issued in 1834. In 1838 Sir Andrew Combe, an eminent English physician, published an English edition of the work, so as to give it greater publicity in the British Isles. Probably no fairer or more impartial estimate of the value of Beaumont's contribution to science has been made than that of Sir Andrew in his preface to the British edition. Answering the objection that Beaumont had made no original discovery in the physology of digestion, this advocate claims that by "separating the truth clearly and unequivocally from the numerous errors of fact and opinion with which it was mixed up, and thus converting into certainties points of doctrine in regard to which positive proof were previously inaccessible, he has given to what was doubtful or imperfectly known

a fixed and positive value which it never had before, and which, being once obtained, goes far to furnish us with a clear connected and consistent view of the general process and laws of digestion."



CLAUDE BERNARD, PHYSIOLOGIST.
1813—1878

CHAPTER IV.

GLYCOGENIC FUNCTION OF THE LIVER—VASO-MOTOR NERVES—CLAUDE BERNARD.

"For a man to be an investigator of the first order two gifts are perequisite it is not merely necessary to possess a well-ordered and what we may term a philosophic imagination, to possess a mind that is capable of balancing phenomena, seeing their relationship and deducing problems that have to be solved and the way in which to solve them; there must be something more, namely, a mechanical ability, a love for technique, and a capacity to construct and manipulate the appropriate instruments. This is particularly necessary in connection with physiological resarch."—Adami

The real life of every notable character lies in the story of his achievement, rather than in how he passed his days. Human interest, however, loves to dwell on the details of how he moved among his fellowmen and the vicissitudes that befel him on his path through life. Often in the lives of our greatest men these details which constitute the human touches have not been recorded. Not every Johnson has his Boswell, and we must content ourselves with the fragmentary data that have been preserved. Such has been the fate of Claude Bernard, the first centenary of whose birth is now the subject of commemoration.

Early Life and Education—Let me give a brief summary of his life. He was born on July 12th, 1813, of humble parentage; his father owned a small farm at St. Julien, near Lyons, France. The vintage of the little estate which was situated in the wine district of France, provided the family revenue. The property eventually came into the hands of the son, who spent his summers there within view, on clear days, of the white summits of the Alps. Bernard received his early education at his native village and afterwards at Lyons. His education was, however, cut short by necessity, which turned him to practical pharmacy as a means of earning a living. The young man possessed that "fine frenzy" which makes "the lunatic, the lover and the poet" of "imagination all compact," and was on the point of giving up the calling which had engaged his attention for two years, for literature. His literary aspirations drew him towards the dramatic art, and it is hard to predict what the future physiologist might have given to the world had not the divine flame been smothered by a more prosaic career of investigator. He was the author of a comedy, "The Rose of the Rhone," which had met with a certain amount of success. But destiny had reserved Bernard for another and very different calling. He submitted his work to the great French critic, St. Marc Girardin, who, while recognizing its merit, advised the young aspirant to literary fame to pursue a more lucrative calling, to engage in some pursuit in which he could earn his bread and to court the Muses only in his leisure moments. "You have studied pharmacy," said the critic, "study medicine; you will thereby much more surely gain a livelihood." Bernard followed this advice with heart and soul, de-

fraying his expenses by tutorage. The literary longings began to fade as the young savant waxed warm with his medical studies. Anatomy and physiology claimed the greater portion of his attention and energy. His remarkable manual dexterity, in which he was particularly fortunate, rendered his dissections of singular completeness and value. The chaotic condition of physiology of the time (1840) served to awaken in his mind a desire to solve problems by direct experimental appeal to nature. He was one of the first to employ animal experimentation, or vivisection. In 1841 he attracted the attention of the great Majendie, then the leading physiologist of France, also Professor of Medicine in the College of France. Majendie is described as being in manner abrupt and even rough and rude. At first he took little notice of Bernard, his new interne, but was soon impressed with the young man's dexterity and skill. One day while Bernard was busy at his dissecting, Majendie blurted out: "I say, you, there. I take you as my preparateur at the College of France." And it was not long before the master had occasion to say in his gruff way as he left the class-room: "You are a better man than I am." Bernard's career as physiologist may be said to date from this appointment in 1841.

Claude Bernard was of a retiring, silent nature, difficult to understand and often misunderstood. Michael Foster described him as "tall in stature, with a fine presence and a noble head, the eyes full at once of thought and kindness; he drew the look of observers upon him wherever he appeared. As he walked the streets passers-by might be heard to say, 'I wonder who that is; he must be some distinguished man.' "

The Productive Period—Bernard had shown the precious metal of his genius before he was far on in his twenties. Nearly all of his great achievements were accomplished during the period of his life which ended with 1860. The essential results of his two greatest discoveries, the glycogenic function of the liver and the vaso motor nerves were gained prior to 1850, before he was 37 years old. He is illustrative of Osler's declaration that the world's best and most important work was mainly done by young men, for further example: Morgagni's germinal idea, which made him the father of modern pathology, came to him when he was scarcely twenty; Auenbrugger began his work upon percussion when he was under twenty-five; Laennec undertook the problem of constructing a system of auscultation in his early twenties and published his book when he was not yet thirty-five.

All significant work in medicine has had its basis in observation, not theory. Men have been prone to theorize too much and to observe too little. For two thousand years the learned men of Europe debated as to whether this or that place was the site of ancient Troy, or whether there ever was such a place at all. It remained, however, for a retired man of business, Schliemann, to decide the question. He said, "Let us go and see," and, at the expense of a few thousand pounds, he went and found Troy and Mycenae and revealed or discovered the whole matter—"The most tremendous and picturesque triumph of the scientific method over mere talk and pretended historic learning," says Ray Lancaster, "which has ever been since human

record has existed." Emerson has said: "I am impressed with the fact that the greatest thing a human soul ever does in this world is to see something and tell what it saw in a plain way. Hundreds of people can talk for one who can think, but thousands can think for one who can see. To see clearly is poetry, philosophy and religion all in one." And we might add, that rare quality of mind which enables its possessor to see clearly is the sine quo non of the true scientist.

Gastric Digestion—Among Bernard's earliest investigations was that of gastric digestion. It was important chiefly as a prelude to the momentous discoveries he afterwards made. He was the first to inquire into the differences to be found between the digestive apparatuses and functions of plant-eating and meat-eating animals—between the herbivora and carnivora. The former thoroughly masticate their food, while the latter bolt theirs. This instinct is explained by the fact that the food of the plant-eating animal contains a relatively large amount of starch, requiring thorough admixture of saliva as an aid to its digestion. Those animals subsisting on meat-protein do not require the aid of the saliva, which accounts for the rapidity with which they devour their food. From this Bernard turned to study the function of the pancreatic juice. Up to this time the pancreas had been passed over in silence by the physiologists of the day. He demonstrated its three-fold action: "He showed that it, on the one hand, emulsified, and, on the other hand split up into fatty acids and glycerine, the neutral fats that are discharged from the stomach into the duodenum. He proved it had a powerful action on starch, converting it into sugar." The study of the action of the pancreatic juice upon proteins begun by Bernard was continued by Kuhne, his pupil, who investigated the action of extracts of the gland. Pancreatic juice as secreted does not possess proteolytic powers. This change under normal conditions is brought about by the activating substance, enterokinase, contained in the succus entericus producing as soon as the pancreatic juice enters the gut, the change from the inert typsinogen to trypsin, thus acquiring an activity over proteins superior to that of any other digestive juice. (Starling). Up to Bernard's time the principal role of digestion had been confined to the gastric juice. With his discoveries it became clear that the action of the gastric juice on the food in the stomach was simply preliminary to intestinal digestion and that the chief work in the preparation of the food for absorption was accomplished by the pancreatic juice.

Discovers Glycogenic Function of Liver—Important as were his numerous contributions to our knowledge of physiology, Claude Bernard is probably best known as discoverer of the glycogenic function of the liver. The story of his discovery is interesting and well worth relating. The dominant opinion among physiologists when Bernard began his work was to the effect that animals and plants presented a chemical contrast to each other. The plant built up such organic compounds as fats, carbohydrates and proteins out of inorganic elements; the animal feeding on the plant received these organic compounds into its body resolving them into inorganic substances, at the same time using that resolution for the needs of life. While the animal modified vegetable proteins, carbohydrates and fats so as to give them an animal character, it never made anything new. It was maintained that

the animal body never manufactured any of these three compounds, that all or any of them present in the animal body had been taken into it with its food.

Such was the current belief among physiologists of France at the beginning of the fourth decade of last century. The first heresy was uttered by Liebig who proved that the fat accumulated in the bodies of fattened geese exceeded greatly the quantity of fat in the intake of food, and furthermore that when a cow was fattened, the excreta during the fattening period contained as much fat as the food taken. At this time Bernard undertook his researches on the physiology of sugar. His first discovery was that cane sugar acted upon by the gastric juice was changed into dextrose (glucose). It was his intention to study the three great classes of foods, but he found it necessary to confine his attention to the carbohydrates owing to the fascinating problems suggested by diabetes. He set about to discover the cause of the excess of sugar in diabetes with the hope of finding a remedy for the disease.

Having previously satisfied himself that no dextrose was present in the alimentary canal, or in the portal blood, Bernard fed a dog on meat only; killing the animal at the height of digestion he found to his great astonishment the blood loaded with dextrose.

"Why!" said he, "if I have made no mistakes I have in this experiment come upon the production of sugar; the liver produces sugar. If the result I have got is confirmed on repetition of the experiment, the liver is the sugar-producing tissue. It manufactures sugar out of something that is not sugar, and within it lies the secret of diabetes. This is a big thing of which I have got hold. I must make sure that I have made no mistake in the experiment, and then push forward as far as possible the lead thus given me."

Bernard's results were confirmed by numerous experiments. He determined that the sugar in question was dextrose, responding to all the tests for dextrose. He also discovered that while this hepatic sugar did not come direct from the food, it was influenced in regard to its quantity by the nature of the food. Starling, however, maintains that in some animals, the carnivora, the liver can continue to supply sugar to the blood on a diet which includes only proteins and fats. Von Noorden explains the fact that proteins yield sugar, by the presence of a carbohydrate group in the protein molecule, which is split off during pepsin-hydrochloric acid digestion.

Bernard eventually came to the conclusion that sugar was not formed immediately from the elements whatever they might be which the blood brought to the liver, but from some substance existing in the liver tissue which was capable of being converted into sugar. In 1857 he announced to the scientific world the discovery of glycogen. Though he made known each step in his discoveries which extended over a number of years, he had the satisfaction of telling the whole story in his own writings, never having experienced the humiliation which is sometimes the lot of pioneers, in seeing their leading conceptions worked out by other minds. To quote his biographer, Sir Michael Foster, "Bernard in the matter of glycogen not only laid the first stone but left a house so nearly finished that other men have been able to add but little."

"No less pregnant of future discoveries," says this biographer, "was the idea suggested by this newly found-out action of the hepatic tissue, the idea happily formulated by Bernard as 'internal secretion.' No part of physiology is at the present day being more fruitfully studied than that which deals with the changes the blood undergoes as it sweeps through the several tissues." The study of these internal secretions constitutes a path of inquiry which has within recent years been pursued with conspicuous success.

To Bernard we owe the discovery of the remarkable fact that temporary diabetes may be caused by puncture of the fourth ventricle. This glycosuria was formerly attributed to direct stimulation of the liver through its nervous connections. It has been found, however, that if the left adrenal is cut off from the left sympathetic nerve, no sugar appears in the urine after the medulla has been punctured, and it is now believed that the stimulus is transmitted by the left sympathetic nerve to the left adrenal, whence it is passed to the right adrenal by the connecting nerves. As a consequence of the medullary puncture the adrenals secrete more actively and the increased flow of the adrenal secretion in its turn brings about an excessive output of sugar by the liver.* A number of toxic influences possibly act in the same way, the glycosuria to which they give rise being partly the result of the action they exert on the diabetic center in the medulla, and partly an effect of their stimulating action on the sympathetic nerves, or on the adrenals directly, thus, in any case, causing hyperfunction of the chromaffin system, with consequent overproduction of sugar by the liver.

Discovery of Vaso-Motor Nerves—Next in importance to the discovery of glycogen was Bernard's discovery of the vaso-motor nerves. "To Claude Bernard," says Sir Michael Foster, "we owe the foundations of the vaso-motor system. He made known to us the existence of vaso-motor nerves and he also made known to us that vaso-motor nerves are of two kinds, vaso-constrictor and vaso-dilator—the two fundamental facts of vaso-motor physiology." The importance of this discovery can hardly be over-estimated when we consider that there is scarcely a physiological problem of any magnitude which does not sooner or later involve vaso-motor questions. The vaso-motor nerves presiding as they do over the contraction and dilation of the walls of the blood vessels, assume an important role in such functions as gastric digestion, blood pressure, heat processes, blushing and various other congestions, or on the other hand, the significant blanching of an organ as in sudden fright.

Among Bernard's minor investigations which might be mentioned is that, into the physiological action of curare, a black resenoid extract prepared by the South American Indians from the bark of strychnos toxifera and used to poison arrows. Owing to its poor diffusibility through animal membranes curare is harmless taken into the alimentary canal, though the minutest quantity introduced into a wound is fatal., Since Bernard's time curare has become an instrument in the hands of the physiologist to enable him to abolish temporarily the movements of the skeletal muscles, enabling him to carry out experiments which could not be made without such aid.

The precise action of carbonmonoxide gas in asphyxia no one understood until Bernard investigated the matter. His experiments

*Futcher Journal A. M. A. December 21, 1912.

led him to conclude that C O was rapidly poisonous to animals owing to the fact that it instantly displaced the oxygen of the red corpuscle and could not itself be subsequently displaced by oxygen. The animal died because the red corpuscles were, so to speak, paralyzed and circulated as inert bodies devoid of the power of sustaining life.

A Friend of Pasteur—It is interesting to note that at a time when physiological opinion favored spontaneous generation, vitalism and such theories, the independent mind of Claude Bernard foresaw what subsequent decades of physiological research have found to approximate the truth on such subjects. He was a firm friend of Pasteur, whom he ably seconded in his efforts to disprove spontaneous generation.

A man is great in proportion to the obstacles he is able to surmount. The subject of this paper illustrates the truth that one who possesses in a high degree the qualities of genius will succeed in spite of his surroundings. His early education, neither adequate nor conducive of the best, together with the keen struggle for a livelihood, and in his early career, the apathy of an unappreciative age and laboratories with meagre equipment, were obstacles which bring into relief the rare qualities that he possessed. Contrast such a condition with the magnificent equipment and endowment of modern scientific research and the facilities for training as they exist today!

Bernard's life was far from being strewn with roses. He was married to a wife who was non-appreciative of his genius. She saw nothing in what to her was empty honor, the homage of the scientific world, when the means which make for affluence were not forthcoming. His two daughters became estranged from him and it is said that one of them who was still living within the last ten years, joined that silly sentimental class of antivivisectionists and endowed hospitals for dogs and cats to atone for the crimes of vivisection which her father had committed. Not only lacked he the sympathy which "in true marriage lies," but he began his work at a time when the physiologist had need of a "real passion for his science and in order to ward off fatal discouragement had to possess his soul of high courage and great patience. So soon as the experimental physiologist was discovered he was denounced; he was given over to the reproaches of his neighborhood and subjected to the annoyance of the police;" Bernard suffered all this.

But conscientious work well performed is not without its rewards and perhaps the greatest is the satisfaction of "something attempted, something done." He was a greater man than Majendie, whose researches were made more or less at random and who had described himself as a "rag picker by the dust heap of science." Bernard always made his experiments with a definiteness of purpose. His contributions to physiology have been greater in number and importance than those of any other investigator. Later in life he enlisted the friendship of Emperor Napoleon III., which resulted in two well equipped laboratories which greatly facilitated his work. His academic opportunities included professorships in the College of France as well as a chair at the Sorbonne. In 1868, he was admitted to the Academy of France and made one of the "Immortals."

The Quest for Truth—As already mentioned, Bernard possessed a faculty that contributed in no small degree to his success as physiologist. Huxley has described an educated man as one whose hand is the ready servant of his will. Often, too, great stress is laid upon the purely intellectual qualities and too little upon that manual dexterity which is so essential to successful work in the laboratory. In fact medicine itself is an art as well as an ensemble of sciences, and the art is as important as the science. As much depends upon the skillful use of the senses, and in surgery, skill in manipulation, as upon the well trained mind. The extreme nicety with which Bernard performed his dissections excited the astonishment as well as the admiration of his associates. It was this faculty which first won him the favor of Majendie. A clumsy experiment is apt to be a poor experiment barren of results, and a patient's chances of life may be jeopardized by an operation poorly performed.

Bernard was active until the end. On what proved to be his deathbed he worked at the revision of proofs of a volume of lectures on operative physiology. He died on the tenth of February, 1878, and was laid in the grave with all the pomp and ceremony of a state funeral. Gambetta eulogized him as one who had never allowed himself to be led away either by party spirit or by the dogmas of a school, or by private feelings. Bernard's work is a model of patient persevering investigation, experiment and research, an unprejudiced and disinterested quest for truth. He lived up to and fulfilled the ideals with which he began his career, ideals aptly expressed: "Truth like beauty is when unadorned, adorned the most." Such ideals have inspired men of light and leading of all time; they inspire medicine today, ideals old yet always new, and we may say with Kipling:

"The men bulk big on the old trail, our own trail, the out trail,
They're God's own guides on the Long Trail, the trail that's always new."

CHAPTER V.

RESPIRATION

The ancients speculated upon the physiology of respiration; Aristotle (384 B. C.) contended that the function of breathing was to cool the blood. It was noticed that animals over-heated from exertion breathed more rapidly, hence the inference. Galen (131-203 A. D.) also maintained that the air inspired served to regulate and to cool down the innate heat of the heart; that the peculiar action of the chest wall seen in respiration introduced into the blood the air required for the regeneration of vital spirits in the left side of the heart, whence by the arterial route they were distributed throughout the body. Galen also recognized the necessity of ridding the body of "fulginous vapors" produced by the innate fire in the heart which act was accomplished by expiration. In the latter part of the fifteenth century, Leonardo da Vinci, painter, mathematician and naturalist, disproved the fallacy that air simply cooled the blood in respiration. He found that air was consumed by fire and that animals could not live in a medium incapable of supporting combustion. This is the first record in the history of science which pointed to the fact that the function of air in respiration depended upon its chemical composition and not upon its physical properties.

It is evident that no real advance could be made in the physiology of breathing until the circulation of the blood had been demonstrated. Furthermore, this department of the science of physiology lagged until the chemist appeared on the scene. Harvey had pointed out that as the blood went to the lungs from the right side of the heart thence to the left auricle a marked change took place, the blood assuming a bright arterial hue. The cause which resulted in this peculiar change, Harvey was unable to discern, nor did it become known until a much later day, when scientists became familiar with the characteristics and constituents of atmospheric air.

Mechanics of Respiration. The first real knowledge on the mechanics of respiration we owe to Borelli. Applying the knowledge of muscular contraction on the one hand, and atmospheric pressure on the other, he taught that inspiration consisted of the entrance of air into the chest by virtue of atmospheric pressure, the thorax being enlarged by the muscular contraction of its walls; expiration consisted mainly in a cessation of muscular contraction. Borelli broke with the ancient view that the function of breathing was the cooling of the excessive heat of the heart or the ventilation of the vital flame. "So great a machinery and vessels and organs of the lungs," he continues, "must have been instituted for some grand purpose; and that we will try to expound, if possible, though we shall stammer as we go along." Again he insists, "Air taken in by breathing is the chief cause of the life of animals." It is more important than the heart and the circulation of the blood.

The Work of Boyle. Now we turn to the English school. Robert Boyle (1627-1691), perhaps the most renowned physicist of his time, by means of the air pump made many researches on the "spring" of air. He showed, among other things that a flame was extinguished in a partial vacuum and that in a more complete vacuum not only the flame but the lives of small animals such as the mouse ceased very quickly. Here we see that the phenomena connected with the burning candle closely resembled the phenomena of life; furthermore that air whatever it might be, and not the mechanical movements of the chest wall was necessary for the continuance of life. Boyle lived at Oxford for many years and while there made important improvements in the air pump and in a long series of experiments with it made various discoveries in the properties of air and the propagation of sound. He was at the same time an ardent student of theology. He was advised to enter the church, but declined, feeling that his writings on religious topics would have greater weight coming from a layman than from a paid clergyman. As a man of science he was the first to carry out the principles of Bacon's Novum Organum.

The next step was taken by Robert Hooke, who was for some time assistant to Boyle. Hooke was born on the Isle of Wight, in 1635. He was destined for the church, but ill-health diverted his career into other channels, which gave scope for his precocious mechanical genius. His personal appearance is described as very unattractive; his hair being in dishevelled locks over his haggared countenance. He possessed an irritable temper and was much given to spending his time in solitude.

To him Boyle was endebted for valuable work in connection with the perfecting of his air pump. He was one of the earliest and most zealous users of the microscope; a volume entitled Micrographia, contains an account of his many "Observations Made on Minute Bodies of varied kinds by magnifying glasses." Hooke's microscopic studies on cork lead to the adoption of the term "cell" as the histologic unit. He was curator of the Royal society, at a meeting of which he demonstrated before the Fellows an experiment on artificial respiration, which had been made before and many times since. The uniqueness of the experiment consisted in the important conclusions which Hooke made. The experiment consisted in opening the thorax of a dog and substituting the movements of the chest wall by respiratory movements accomplished by means of hand bellows, the nozzel inserted in the trachea. This proved that the mechanical movements of the chest wall were only of a secondary importance and that the whole business of respiration was carried on in the lungs. This fact was further proven by inflating the lungs to their utmost capacity and keeping them distended by a powerful blast allowing the air to escape continually through minute holes pricked in the lungs. This showed that life could be maintained even in the absence of the artificial movements so long as the parenchyma of the lungs were so subjected to a fresh supply of air. Therefore the secret of the change from venous to arterial blood depended upon the exposure of the blood to fresh air which was in the course of life accomplished by the bellows-like action of the chest wall and diaphragm.

Change in Color of Venous to Arterial Blood.—Richard Lower, 1631, concluded that the change in color, venous to arterial, blood was due to the exposure of the blood to the air in the lungs; he drew the further conclusion that the change in color was due not to the exposure alone, but to the fact that the blood took up some of the air; that is, according to Lower, arterial blood differed from venous in that it contains air. The blood gave up its "fresh air" in the course of the circulation, hence the necessity of a constant supply of fresh air for the maintenance of life. "Were it not for this, we should breathe as well in the most filthy prison as among the most delightful pastures." * * * "In fact," he continues, "where a fire burns readily there we can easily breathe." Note that there was no mention that only a part of the air was taken up by the blood. The common knowledge of the time was that air was a simple substance, not a mixture of several elements as we know it today.

Mayow and His Researches.—The next contribution to the subject of respiration was that of John Mayow, born in London in 1643. Mayow was a lawyer by profession and science was his avocation. Many valued contributions to medical science were made by men whose lives were spent in other callings. Priestly who discovered oxygen was a Unitarian minister; Schleiden, whose name is connected with the cell theory, was a lawyer; Schwann was a botanist; Metchnikoff is a biologist. Thus many of the important discoveries germain to medicine were made by men whose work was inspired by the fascination of the subject in hand—the avocation of their leisure moments. Of Mayow it was said he took his degree in law and "became noted for his practice therein." Mayow's published works consisted of four tracts—de sal nitro et spiritu nitro aero; de respiratione; de respiratione feotus in utero et ovo; de motu musculari et spiritibus animalibus. He showed that it was not the whole air which was necessary for respiration, but only a portion, and that particular constituent of the air which has since become known as oxygen. In the language of the chemists of his time, for he was essentially a chemist, Mayow endeavors to prove "that this air which surrounds us, and which, since by its tenuity it escapes the sharpness of our eyes, seems to those who think about it to be an empty space, is impregnated with a certain universal salt, of a nitro-saline nature, that is to say, with a vital, fiery, and in the highest degree fermentative spirit." The word "salt" was used by the seventeenth century chemist to designate any substance not distinctly metallic or liquid.

Mayow sums up the conditions necessary for combustion; "concerning fire it must be noted that for the ignition of this it is necessary that igneo-aereal (evidently oxygen) particles should either preexist in the thing to be burnt or should be supplied from the air. Gunpowder is very easily burnt by itself by reason of the igneo-aereal particles existing in it. Vegetables are burnt partly by means of the igneo-aereal particles existing in them, partly by help of those brought to them from the air." This early chemist recognized the fact that in combustion we have a chemical combination with the substance burnt, and as a result an actual increase in weight. He experiments with antimony, which he burns by focusing the sun's rays by means of a lens; by weighing the substance he finds an increase in weight which he attributes the "insertion into it of igneo-

aereal particles during the calcination. As we shall see more than a century later Lavoisier arrives at the same conclusion. But Mayow did not stop here. He proceeded to point out the identity of burning and breathing:

"If a small animal and a lighted candle be shut up in the same vessel, the entrance into which, of air from without is prevented, you will see in a short time, the candle go out; nor will the animal long survive its funeral torch. Indeed, I have found by observation that an animal shut up in a flask together with a candle will continue to breathe for not much more than half the time than it otherwise would, that is without the candle. * * * The reason why the animal can live some time after the candle has gone out seems to be as follows: The flame of the candle needs for its maintenance a continuous and at the same time a sufficiently full and rapid stream of nitro-aereal particles. Whence it comes about that if the succession of nitro-aereal particles be interrupted, even for a moment, or if these are not supplied in adequate quantity, the flame presently sinks and goes out. Hence, so soon as the igneo-aereal particles begin to reach the flame scantily and slowly, it is soon extinguished. For animals, on the other hand, a lesser store of the aereal food is sufficient, and one supplied at intervals, so that the animal can be sustained by aereal particles remaining after the candle has gone out. Hence it may be remarked that the movements of the collapsed lungs not a little help towards the sucking of the aereal particles which may remain in the said flask, and towards transferring them into the blood of the breathing animal. Whence it comes about that the animal does not perish until just before the aereal particles are wholly exhausted. * * * We may infer that animals and fire deprive the air of particles of the same kind."

Mayow's account of the mechanics of respiration would need little or no revision for a modern text book on physiology. He showed that the air entered the lungs during respiration solely by atmospheric pressure. He makes use of the experiment whereby a collapsed bladder is placed into a bell-jar, the bladder expanding as the air in the jar is exhausted by means of an air pump. He taught that in inspiration the chest is enlarged by the descent and contraction of the diaphragm and by the raising of the ribs. Mayow further tackles the raison d'etre of breathing in which he shows that something necessary to sustain life passes from the air into the blood. "We have no right," said he, "to deny the entrance of air into the blood because on account of the bluntness of our senses we cannot actually see the vessels by which it makes its entrance."

These extracts go to show how mature the views of the seventeenth century school of English physiologists, Boyle, Hooke, Lower and Mayow in particular, were. Mayow by his nitro-aereal or igneo-aereal substance evidently meant oxygen. Their work was, however, allowed to slumber, until the scientific path was retraveled by their successors nearly a century later.

Summary Prior to the Beginning of the Eighteenth Century.—Van Helmont (1648) had discovered some of the properties of carbondioxide. He showed that a gas was formed from fermentation or the combustion of carbon and from the action of vinegar on certain carbonates, and that this gas was incapable of supporting combustion. Boyle (1670), as we have seen, proved that air was necessary to the life of all animals, even those which lived under water. Bernoulli, at a later date, showed that the existence of aquatic animale depended upon air held in solution in water. Hooke exposed

the lungs of a living animal and maintained the vital processes by means of artificial respiration, showing that the vital processes depended upon a continual change of air in the lungs. Fracassati drew attention to the fact that the red color of the upper surface of a clot was due to its exposure to air. Mayow (1674) advanced the view that air contained a principle capable of supporting combustion, and which, absorbed in respiration, changed venous into arteral blood and was the cause of heat developed in animal bodies.

Eighteenth Century School.—Among the early eighteenth century contributors to our knowledge of respiration was Stephen Hales, born 1677, who, by the way, was not connected with the medical profession. He received his M. A. degree at Cambridge in 1703, and Bachelor of Divinity in 1711. He was a clergyman by profession, a calling which he followed until his death in 1761. He is chiefly known as the inventor of a "ventilator," by means of which fresh air was introduced into jails, mines, hospitals, and ships' holds. Four years after the introduction of Hales' invention into the Savoy prison only four prisoners died, whereas the mortality before its introduction had been as high as one hundred a year. Devoted as was Hales to the church, he was even more devoted to science. He was the first to determine blood pressure by actual experiment on the living animal.

Next in chronological sequence is Joseph Black, an eminent chemist born at Bordeaux in 1728, where his father was engaged in the wine trade. Both parents were of Scotch descent. In 1746 Black entered the University of Glasgow, where he studied chemistry under Dr. Cullen. He, however, graduated from the University of Edinburg in 1754. In a graduation thesis he proved that the causticity of lime and the alkalis is due to the absence of carbonic acid present in limestone. He did not use the term carbondioxide but instituted the term "fixed air." The former name was first used by Lavoisier in 1748. Black's work was a distinct contribution to chemistry. In 1756, he became professor of anatomy and chemistry at Glasgow, but shortly become professor of the Institutes of Medicine. In the meantime he practised his profession and found opportunity for original investigation. In 1766 he was transferred to a similar position in Edinburgh. His lectures were noted for their clearness and what is perhaps the best testimonial to any lecturer, his classes became the largest and best attended in the university. Though of delicate constitution, by constant care he lived to the fairly ripe age of seventy-one.

Black had been anticipated in his discovery of "fixed air" by Van Helmont, whose researches had been made a century earlier. In other words, he had re-discovered the gas later to be known as CO^2. By using clear lime water, he was able to show that "fixed air" was given off in fermentation, in expiration and that it was a product of burning charcoal. The chemical formula for clear lime water is Ca $(OH)^2$, which in the presence of "fixed air," CO^2, becomes Calcium Carbonat, $CaCO^3$, which is precipitated as chalk, and water (H^2O). The result of the chemical reaction is, of course, a reduction in the causticity of the original substance.

I quote the following extracts from his treatise on chemistry:

"I had discovered that this particular kind of air, attracted by alkaline substances, is deadly to all animals that breathed it by the mouth and nostrils to

gether, but if the nostrils were kept shut I was led to believe that it might be breathed in safety. I found for example that when sparrows died in it in ten or eleven seconds, they would live in it three or four minutes when the nostrils were shut by melted suit. And I convinced myself that the change produced on wholesome air by breathing it consisted chiefly, if not wholly, in the conversion of part of it into fixed air. For I found, that by blowing through a pipe into lime water, the lime was precipitated, and the alkali was rendered mild. * * * In the same year I found that fixed air is the chief part of the elastic matter, which is formed in liquids in the vinous fermentation. Van Helmont has indeed said this. But it was at random that he said it was the same with the Grotto del Cane in Italy (but he supposed the identity because both are deadly), for he had examined neither of them chemically, nor did he know that it was the air disengaged in the effervescence of alkaline substances with acids. I convinced myself of the fact by going to a brew house with two phials, one filled with distilled water and the other with lime water. I emptied the first into a vat of wort fermenting briskly, holding the mouth of the phial close to the surface of the wort. I then poured some of the lime water into it, shut it with my finger, and shook it. The lime water became turbid immediately."

Black goes on to criticise Van Helmont's pronouncements as mere chance statements. He, himself, verified all his conclusions by repeated experiment.

As Black re-discovered under the term "fixed air" that which Van Helmont had recognized a century before, so Mayow's igneo-aereal salt or spirit was re-discovered by Priestly and Lavoisier.

Priestly and His Dephlogisticated Air: With the name of Joseph Priestly, perhaps more than any other, is associated in the modern mind the discovery of oxygen, though he did not make use of the term. Of him Frederick Harrison has said:

"If we choose one man as a type of the intellectual energy of the eighteenth century we could hardly find a better than Joseph Priestly, though his was not the greatest mind of the century. His versatility, eagerness, activity and humanity; the immense range of his curiosity in all things physical and social; his place in science, in theology, in philosophy and in politics; his peculiar relation to the Revolution, and the pathetic story of his unmerited sufferings, may make him the hero of the eighteenth century."

He was born near Leeds, England, in 1733, and died in the United States in 1804. His boyhood was uneventful. His family was described as "simple, sober, honest, God-fearing folk, staunch Calvinists and deeply religious." The son inherited these qualities and entered the ministry as a Unitarian preacher, an act which was particularly offensive to the orthodoxy of the time. Benjamin Franklin, to whom Priestly is endebted for the incentive for scientific study, refers to him in a letter as an "honest heretic." And continuing in Franklin's charactersitic style, he says:

"I do not call him honest by way of distinction, for I think all the heretics I have known have been virtuous men. They have the virtue of fortitude, or they would not venture to own their heresy; and they cannot afford to be deficient in any of the other virtues, as that would give advantage to their many enemies; and they have not like orthodox sinners, such a number of friends to excuse or justify them. Do not, however, mistake me. It is not to my good friend's heresy that I impute his honesty. On the contrary 'tis his honesty that has brought upon him the character of heretic."

Priestly was thirty years old when Franklin was sixty. Priestly like Franklin was well informed on a variety of subjects. He wrote learnedly on politics, religion and on science, particularly on pneumatic chemistry. Boswell dubbed him a "literary Jack-of-all-trades," and he was busy with proof sheets until the day of his death. His pamphlets on politics and religion were so much opposed by the orthodox theologians of his day that they answered his arguments by burning his house and dispoiling his belongings, a peculiar way that the so-called orthodox theology has had in the past of dealing wih those bold intrepid spirits who have dared to stand for what they believed to be the truth. His home surroundings in Birmingham became so unpleasant that in self-defense he set sail for America, here to breathe the atmosphere of civil and religious freedom. He was offered the professorship of chemistry in the University of Philadelphia, but the following year moved to Northumberland, a town on the Susquehanna, a hundred and thirty miles northwest of Philadelphia. He lived and worked until his death, which occurred in February, 1804.

Priestly endeavored to change back to its original condition, air that had been breathed, or which had failed to support the flame of a candle. He eventually succeeded by means of vegetation. First he experimented by placing a sprig of mint into a glass jar standing inverted over a vessel of water. Parenthetically, Priestly invented the pneumatic trough, which has been found so convenient in experimenting with gases. When the sprig of mint had been growing some months, the air within the vessel would not extinguish a flame nor act deleteriously to small animals, such as the mouse, placed therein. The growing plant really contributed to the flame or the animal that was placed in the vessel. Further experiment showed that a growing plant placed in a vessel in which a flame had been extinguished would in time render the atmosphere in the jar capable of supporting either flame or animal life. This lead him to conclude: "That plants, instead of affecting the air in the same manner with animal respiration, reverse the effects of breathing and tend to keep the atmosphere sweet and wholesome when it is become noxious in consequence of animals either living and breathing or dying and putrifying in it."

Priestly's researches might have been more fruitful in results had he not been dominated by the phlogiston theory, a term devised by Stahl. Phlogiston, from phlogistos, burnt, was a hypothetical principle of fire regarded as a material substance. Every combustible substance was a compound of phlogiston and the phenomenon of combustion was due to a separation of the compound into its component elements.

Priestly was able to obtain the same gas by heating mercuric oxide, and from red precipitate. But he could not get away from the phlogiston theory. Air supported combustion because it took up phlogiston given out by the burning body. Common air supported combustion in proportion as it was free from phlogiston. He prepared oxygen in 1774, that is he discovered that the gas he prepared was part of the common air, which supported life and combustion. Venous blood was blood laden with phlogiston. Blood exposed to dephlogisted air gave up its phlogiston and became bright arterial blood.

Some idea of the scope of Priestley's researches may be inferred from the mere catalogue of his discoveries. He is credited with discovering dephlogisticated air (oxygen) hydrochloric acid, sulphur dioxide, nitrosulphuric acid, sulphuretted hydrogen, and the isolation of amonia gas.

Lavoisier and His Work.—Antoine Laurent Lavoisier was born in Paris in 1742, ten years later than the date on which Priestly first saw the light of day. As scientist his career was practically contemporaneous with that of Priestly, who made the same momentous discovery, working independently. In 1775, a year after Priestly had prepared his dephlogisticated air (oxygen), Lavoisier published his paper "On the nature and principle which combines with metals during their calcination." In this paper he showed that metals on being "burnt" did not give up phlogiston to the air but took something from the air; they on becoming metallic oxides, increased in weight. Lavoisier dealt the death blow to the phlogiston theory and was in a sense the real discover of oxygen. He proved that the principle which combined with metals when calcined was the principle of acidity. He says: "I shall therefore designate dephlogisticated air, air eminently respirable, when in a state of combination or fixedness by the name of 'acidifying principle.' or, if one prefers the same meaning in a Greek dress, by that of 'oxygine' principle." Lavoisier discovered oxygen and gave it the name by which it will henceforth be known. He made further experiments in connection with respiration which he concluded to be "a combustion, slow it is true, but otherwise perfectly similar to the combustion of charcoal." He eventually saw, however, that some of the oxygen inspired had other use than the production of carbon dioxide.

It was not. however, until the early decades of the nineteenth century that the view that oxidation took place in the lungs gave way to the accurate theory of tissue respiration. In 1837, Gustave Magnus proved that both venous and arterial blood contained oxygen and carbon dioxid.

Hydrogen was discovered by Cavendish in 1781, when he also discovered the composition of water. Nitrogen was discovered in 1772 by Rutherford. Oxygen was prepared by Priestly in 1774 and recognized by Lavoisier the following year. Carbonic acid gas, or carbon dioxide was first discovered by Van Helmont in 1640 and rediscovered and defined by Black in 1757.

THE NERVOUS SYSTEM.

The progress of knowledge of the nervous system has been very slow. Most of the other viscera were known to the ancients before the brain was recognized. The word "brain" is not to be found in the Bible. The ancient Hebrews evidently looked upon the heart as the seat of the soul. The kidneys were the habitation of the mind, while the tender emotions were referred to the bowels. Plato was perhaps the first to assign the supreme seat of the mind to the brain, but his views were purely speculative, inasmuch as he confounded the substance of the brain and of the spinal cord with the marrow of bones. Aristotle, about 335 B. C., examined the brain for himself and concluded that its function had nothing whatever to do with the mind, but that it was a refrigerating organ which cooled the blood for the heart. He reasoned according to the knowledge of his time. The brain was apparently an insensible and inexcitable organ as contrasted with the heart, which is the opposite. Hippocrates recognized how soon animals became unconscious from the loss of blood, or how changed by blood poison or by the heated blood of fever; hence the inference by Aristotle that the conscious mind resided in the blood and that the great central organ, the heart, was the seat of the soul. The arteries (from the etymology, air tubes or wind pipes) found empty after death, were supposed to carry air or "ethereal" spirits to the rest of the body. It was this great blunder that delayed for centuries, virtually until Harvey's time, all progress of knowledge of the true function of the heart. Hippocrates maintained that the brain was a gland. With this supposition subsequent writers ventured the suggestion that the brain secretion was a subtile fluid which they designated "animal spirits." The authority of such names as Hippocrates and Aristotle forbade first hand investigation for fully five centuries. It must not be overlooked, however, that amid all this guessing, Alcmaeon (about 500 B. C.), an anatomist and physiologist, taught that the brain was the seat of the mind and that all sensation traveled to the brain by means of the nerves. He spoke of the nerves as "tendons" which misconception held sway until Descartes, the philosopher, showed the difference between tendons and nerves.

About 300 B. C. sprung up the Alexandrian school of anatomists and physiologists of whom Herophilus and Erastistratus were chief who dissected the brain and traced to it the nerves as Alcmaeon had done. They even went so far as to distinguish nerves of sensation and nerves of motion, but were still hampered by Alcmaeon's "tendons." "When Greece fell under the subjection of Alexander, mind went into exile, and its first asylum was the city of the conqueror." Under royal patronage the study of anatomy and physiology and surgery made great progress. Galen spoke of Herophilus and Erastistratus as possessing more accurate knowledge of the human body than any one before their time. Herophilus was the first anatomist of importance in the annals of medicine. He is said to have discovered the lacteal

vessels, and the construction of the eye, including the retina. Galen speaks of Herophilus as having a very intimate knowledge of the anatomy of the nervous system. The term, "torcular Herophili" signifies the "press" or dilation at the junction of the superior longitudinal, lateral and occipital sinuses first described by Herophilus. Herophilus and his associates performed vivisection upon condemned criminals. Not only did medicine progress during this early period (about 300 B. C.), but literature, philosophy, mathematics, natural history and astronomy flourished as well under the patronage of Ptolemy. A great part of the record of this fruitful period was lost during the seventh century of the Christian Era, with the destruction of the great Alexandrian library.

"The Brain the seat of Thought and Sensation:" Galen, A. D. 160, overthrew Aristotle's theory in regard to the brain and showed it to be the seat of thought and sensation. Aretaeus (170 A. D.) taught that the brain controlled the muscular movements of the body by means of nerves originating in the brain. He recognized the crossing of the nerves so that injury to one hemisphere produced paralysis on the opposite side. If injury occurred in the cord below the medulla the paralysis was on the same side as the injury. The seat of the soul was, however, in the heart.

Andreas Vesalius (1514-1564) declared that the "brain in appropriate structures, and in organs properly subserving its work manufactures the animal spirit which is by far the brightest and most delicate, and indeed is a quality rather than a natural thing. * * * Nerves serve the same purpose to the brain that the great artery does to the heart." The nerves he regarded as the "busy attendants and messengers of the brain." Vesalius, however, is free in the use of such terms as "vital soul," "vital spirits," "animal spirits," which meant so much to the physiologist of his day and so little to us of the twentieth century. While these meaningless terms make a great deal of his work unintelligible, yet there abound throughout gleams of truth as we understand it today. He showed that by severing a nerve or by ligation it was possible to abolish the action of the nerve upon the muscle. Regarding the brain he says: "But how the brain performs its functions in imagination, in reasoning, in thinking and in memory, I can form no opinion whatever."

Nearly a century later we come to the conclusions of von Helmont and of Descartes which were much less to the point than the expressed opinions of Vesalius. One placed the seat of the soul in the pylorus; the other in the pineal gland.

Malpighi devoted much attention to the histology of the nervous system but said practically nothing about the functions of the nerves.

Thomas Willis: Perhaps the most important investigator of the seventeenth century into the anatomy and physiology of the nervous system was Thomas Willis. He was born in Wiltshire, England, in 1621, educated at Oxford where he graduated with the degree of M. A., 1642. He eventually entered upon the study of medicine and on graduation was appointed to a professorial chair in Oxford. Here he taught, practised medicine and pursued his scientific researches. In 1666 he located in London where in the language of a

contemporary "he became so noted and so infinitely resorted to, that never any physician before went beyond him or got more money yearly than he." Willis possessed a practical knowledge of the structure and functions of the brain, both in health and disease. His name today is familiar to all students of anatomy in the "circle of Willis," which designates the combined arterial structure at the base of the brain. Sir Michael Foster is inclined to depreciate the work of Willis. The value of his book is much above the worth of the author. It appears that Willis' thirst for fame was much greater than his love for truth. Richard Lower, a contemporary was the real man of science of his day. Willis is said to have appropriated the work of Lower and other earnest men and to have published it as his own. Throughout the work of this period we still have to deal with the "corporeal soul," "animal spirits," "sensitive soul" and similar phrases.

Muscle Irritability: Frances Glisson, an Englishman, born, 1597, came upon the truth of the relation of nervous influence to muscular contraction. Educated at Cambridge, he became a Fellow and lecturer in Greek in his Alma Mater. On the publication of Harvey's work, in 1628, Glisson determined to turn his attention to medicine, and six years later he received his M. D. degree. He did not go abroad as Harvey did but pursued his medical studies in London. He was soon appointed Regius Professor of physic at Cambridge, but it seems did not spend much time there, as the social atmosphere was not congenial to him. Cambridge was strongly Royalist, while Glisson was a very pronounced Presbyterian. He served in a professional capacity in London during the great plague of 1665. He died at the age of eighty years. He is probably best known for his work on the liver. His name is familiar to us in connection with the capsule covering that viscus. Glisson's studies on the liver lead him to his discovery regarding the peculiar properties of muscle tissue.

Explaining how the bile is discharged into the intestine only when it is needed, he shows that the secretion is greater when the gall bladder and passages are irritated, hence they must possess the power of being irritated. For this peculiar property he suggests the term irritability. The idea was not seized by contemporary physiologists, hence Glisson's work remained dormant until the following century, when Haller made use of the term, and since his day it has become established in physiology and has played an important part in the development of both physiology and pathology.

Goll and Phrenology: A name which has received but slight attention at the hands of biographers is that of Franz Joseph Gall or Goll, best known as the founder of the pseudo science of phrenology, or "bumpology" as it has been contemptiously called. Goll was born in 1758. He took his degree in medicine at the University of Vienna, in 1785, where his studies on brain and mind began. He was an acute observer of phenomena and from a collation of observed facts was the first to demonstrate that the brain was the organ of the whole mind. The modern phrenologist with whom we are more or less familiar, is a disciple of Goll; his name will be remembered as associated with the discovery of certain areas in the spinal cord. Goll died in Paris in 1828.

Bell and Magendie: One of the greatest names in connection with the anatomy and physiology of the nervous system is that of Sir Charles Bell. In fact, his discovery has been placed in importance in the same class as that of William Harvey. Charles Bell was born at Edinburgh, Scotland, in 1774. After graduating from the University of Edinburgh he began the study of medicine under his elder brother John, who had already achieved distinction as anatomist. After graduating he devoted himself to anatomy and surgery. He eventually moved to London, where he worked into a very lucrative surgical practice. His first published work (1798) bore the cumbersome title ,and it was the custom of writers of the time to preface their work with a sentence descriptive of its contents, of "A System of Dissections Explaining the Anatomy of the Human Body, the Manner of Displaying its parts and their varieties in Disease." Four years later Bell published a series of engravings of original drawings showing the brain and nervous system. His drawings are worthy of special mention. His skill as anatomical artist rivaled that of anatomist. He was also the author of a work entitled "The Anatomy of Expression," the object of which was to describe the arrangement by which the influence of the mind is propagated to the musculature of the face and to give a rational explanation of the muscular movements which accompany the various emotions and passions. He emphasized to the physician and surgeon the importance of a knowledge of facial expression in diagnosis, to ascertain the nature and extent of bodily suffering. In these days of the clinical laboratory and multifarous other clinical methods, the ability to make a diagnosis by observation alone which amounted to intuition with the old-time clinicians, is a lost art. This work, which was illustrated by himself, had a wide circulation in his day.

Charles Bell's most important work, however, was the discovery of the double system of nerves issuing from the spinal cord. He discovered that in the nerve trunks are special sensory filaments to transmit impressions from the periphery of the body to the sensorium and motor filaments to convey motor-impressions from the brain or other nerve centres to muscle. He demonstrated that the anterior roots of the spinal cord were motor and the posterior roots sensory.

While in London, he was Professor of Anatomy, Physiology and Surgery in the College of Surgeons. He was knighted by William IV. He returned to Edinburgh 1836 where he became professor of anatomy and surgery. His name is associated with the disease which he was the first to accurately describe, paralysis of the seventh nerve—"Bell's Palsy." He died in 1842.

A name of only less importance than that of Sir Charles Bell is that of Magendie. Magendie has been considered the greatest physician France had produced down to his day. His work on physiology written while in his early thirties was almost immediately translated into English and German. It was a valuable work, inasmuch as it was based upon experimentation. He was the first continental investigator to discover the function of the spinal nerves, and according to Gorton, contributed more to the knowledge of the nervous system than any of his distinguished predecessors. Magendie was

born at Bordeaux, France, in 1783, studied medicine in Paris, where he became demonstrator, and eventually professor of anatomy in the College of France. He died in 1855.

Magendie is described as being abrupt in manner, even to rudeness. His brusque manner has been referred to in his relations with his understudy, Claude Bernard. He seems, however, to have been a brilliant if not very methodical worker. He refers to himself as a ragpicker by the dust heap of science. His work on the nervous system was parallel with that of Sir Charles Bell, and the scope of the work of both is epitomized in the well-known Bell and Magendie Law to the effect that the spinal roots may be divided into afferent and efferent, the anterior roots carrying impulses only from the spinal cord to the periphery, while the posterior roots carry impulses from the periphery to the central nervous system; a nerve fibre cannot be both motor and sensory; we may have both nerve fibres in a single nerve trunk but the fibres in each case are isolated and conduct impulses only in one or other direction.

To Claude Bernard, associated with Magendie in the College of France, we owe the discovery of the vaso-motor nerves.

Broca and the "Speech Center."—In 1861 Paul Broca, an imminent French surgeon, proved that there is a definite locality in the brain which is the seat of articulate speech. This is known today as "Broca's Convolution." Nine years later, thanks to the labors of such men as Hitzig, Ferrier and Charcot, it was shown that each of the special senses has its anatomical seat in the brain. It was also found that each volutary muscle or group of muscles could be made to contract by the excitation of certain "centers" or localities in the surface of the brain. Regarding later progress in brain physiology, Gorton says: "It is worth while to note the stride anatomy has made during the closing years of the nineteenth century, especially in knowledge of the central nervous system of man and animals. Early in the last decade of the century the subject was taken up by German and Italian anatomists, Waldeyer, Nissl, Marchi, Golgi, His, Apathy and others. To Waldeyer we are indebted for the doctrine of neuron as applied to nerve cells, from the Greek word "neuron,' signifying unit. According to this doctrine every cell is a unit having an independent existence, distinct and apart from other cells, though related to them, and may degenerate and die without affecting the existence of the others. Meynart estimates that "the cortex of the cerebral hemispheres alone contains twelve hundred millions of ganglionic cells;" and Donaldson states that three thousand million cells "is a modest estimate of the total number of these neurons in the central nervous system." The doctrine of neurons has been assailed as applied to comparative histology by the distinguished Apathy, and defended among others by Barker, of Johns Hopkins University." The invention of staining processes afforded a powerful impetus to the study of nerve tissues.

By means of animal experimentation Flourens, Luciani and Horsley determined the function of the cerebrum. Removal of the cerebrum from a frog or pigeon caused all its voluntary movements to cease, but did not interfere with the reflexes or the negative func-

tions. The same investigators found that if the cerebrum was removed and the cerebellum left, the animal has sense of appreciation, but fails in muscular coordination. Stephen Hales showed that the spinal cord is necessary for reflex movements and Marshall Hall worked out the whole problem of reflexes. Galvani (1791) studied reflexes by applying electric stimuli to frogs' legs.

Pathologic States of Brain and Nervous System—Apropos of the development of knowledge of the physiology of the nervous system is the evolution of our knowledge of its pathologic states. The insane have suffered much owing to ignorance and misconception on the part of the sane. Ancient nations looked upon the insane as possessed of evil spirits or as "possessed of devils." Later the Greek, Alexandrian, and the Roman, looked upon the insane man as a sick man and he was accordingly treated by means of drugs, baths, exercise and other hygienic measures. A great retrogression took place during the second or third centuries of the Christian era. Theories of demoniac possession again held sway, with the result that the insane were subjected to the utmost cruelty. This attitude continued throughout the Middle Ages. In fact, no marked advance was made until the eighteenth century. Various places of custody were maintained for the insane where they were confined in dungeons, badly clothed and badly fed. The first real advances in their care were made by Philip Pinel, in France. Tuke, in England, and Benjamin Rush, of America, near the end of the eighteenth century. Pinel in 1793 substituted a system of non-restraint and humane treatment for blows and punishments. William Tuke, member of the Society of Friends, was making similar reforms in England. Stahl, early in the eighteenth century, insisted on the essentially sinful character of insanity and this attitude found echo in Heinroth in the early nineteenth century. Religious theories have little by little given place to physiological and psychological explanations until today the insane man is regarded as a sick man. Insanity implies disease organic or functional, just as do other abnormal manifestations.

Note: I am indebted to F. X. Dercum's work on Mental Diseases, 1913, for the data of the last paragraph.

THE CELL THEORY

"The cell theory furnishes the starting point for all modern studies in biology and enables all students to speak the same language," says a twentieth century writer. The recognition of the fact that animals and plants are constructed on a similar plan must be placed among the most important discoveries of the nineteenth century prolific as that century has been in scientific achievement. "No other biological generalization," says Professor Wilson, referring to the cell theory, "save only the theory of organic evolution has brought so many diverse phenomena under a common point of view, or has accomplished more for the unification of knowledge." By the term "cell-theory" is understood the teaching that all animal and plant tissues are composed of units known as "cells," which term as we shall see is inappropriate so far as the actual things designated by it are concerned. The cell-theory is a generalization which places animals and plants on a basis of similarity of structure.

Anticipated in the Seventeenth Century: The cell doctrine was anticipated as far back as the seventeenth century, for it is to a worker of the mid-seventeenth century that we are endebted for the term "cell." Robert Hooke, an English microscopist, experimented with cork, which he declared to be made up of "little boxes or 'cells' distinguished from one another." He made thin sections by means of a pen knife and found them to be all "cellular or porous in the manner of a honeycomb." Malpighi and Leeuwenhoek, in the seventeenth century, made drawings which have been preserved showing the cell structure of plants; we may therefore conclude that the cell theory announced in 1838, was foreshadowed by seventeenth century workers. Wolff, an acute scientific observer in 1759 worked out the identity of plants and animals, as shown by their development. Huxley summarizes Wolff's view of the development of elementary parts as follows: "Every organ, according to him, is composed at first of a little mass of clear viscous nutritive fluid which possesses no organization of any kind, but is at most composed of globules. In this semi-fluid mass cavities are now developed; these if they remain round or polygonal, become the subsequent cells; if they elongate, the vessels; and the process is identically the same whether it is examined in the vegetating point of a plant or the young budding organs of an animal."

Bichat's Contribution: Though his connection with the cell theory is open to question, the name of Bichat is deserving of mention in discussing it. Marie Francois Xavier Bichat, born in France in 1771, is noted as the founder of histology. He studied in Paris under the great surgeon Desault. He was himself made professor of anatomy at the age of twenty-six years, a position which he held until death relieved him of his labors at the early age of thirty-one. It is related

M. SCHLEIDEN,

THEODOR SCHWANN,

Co-founders of the Cell-Doctrine. From Locy Biology and Its Makers.

that he won the attention and admiration of his chief by making a complete extemporaneous report of one of Desault's lectures. Bichat was a most admirable character; he has been described as of "middling stature, with an agreeable face, lighted by piercing and expressive eyes," and as being "in all relations of life most aimable, a stranger to envy or other hateful passions, modest in demeanour, and lively in his manners which were open and free." Two of his works, his treatise on the membranes and his general anatomy are important as the foundation of histology, or the minute anatomy of the tissues. After the ennunciation of the cell theory Bichat's work took on a new phase, namely that of microscopic study of the tissues. Schwann's cell theory was in reality an extension of his work. Bichat's claim for credit in connection with the cell theory has been called into question inasmuch as his investigations were done without the aid of the microscope.

The Cell Theory, 1838: During the first three decades of the Nineteenth century there accumulated a great mass of unconnected observations on the microscopic structure of both animals and plants. "We must clearly recognize," said Tyson, "the fact that for some time prior to 1838 the cell had come to be quite universally recognized as a constantly recurring element in vegetable and animal tissues, though little importance was attached to it as an element of organization, nor had its character been clearly determined."

Eighteen hundred and thirty-eight was an epochal year in biological science, chronicling as it does the ennunciation of the cell-theory by Schleiden and Schwann the result of the combined efforts of botanist and animal biologist. The work of Schwann, however, was more comprehensive and important than that of Schleiden, and to him, therefore, belongs the greater honor.

M. Schleiden was educated for the legal profession and had engaged in the practice of law. He soon abandoned it for medicine, but after graduation devoted himself to the study of botany. Locy describes his work in 1837, stating that he arrived at a new view in regard to the origin of plant cells. This new view though founded upon erroneous observations and conclusions served to provoke discussion. His work acted like a ferment, we are told, in bringing about new activity. Schleiden was noted for his alertness in entering upon controversies, a trait which better befits the lawyer than the man of science whose sole concern should be the quest of truth. His replies to his adversaries were at times vitriolic and he often indulged in bitter personalities. Perhaps his legal training was responsible for this.

His methods of investigation were sound, based as they were on experiment and observation. He conceived the necessity of studying the development of plants in order to understand their anatomy and physiology. The nucleus of the plant cell was discovered in 1831, by Robert Brown. Schleiden seized upon the nucleus as the starting point of new cells but wrongly supposed that the new cells started from a small clear bubble on one side of the nucleus. And yet it was through these inaccurate observations of Schleiden that his co-founder, Schwann, arrived at his general conclusions. An incident is related of the two dining together one October evening when Schleiden

took occasion to relate to his friend his observations and inferences. Schwann was impressed at once with the similarity to his own observations on animal tissues. They at once proceeded to Schwann's laboratory where sections of the spinal cord were examined. Schleiden recognized the nuclei as similar to those he had found in plant cells.

Theodor Schwann: Schleiden and Schwann seem to have been the most diverse personalities. The former was pugnacious and always ready to take up the gauntlet in controversy; the latter was one of the mildest of men. We are endebted to Henle, a name familiar in microscopic anatomy, for what we know of the life of Schwann. This is Henle's description of him: "He was a man of stature below the medium, with a beardless face, an almost infantile and always smiling expression, smooth dark brown hair, wearing a fur trimmed dressing gown, living in a poorly lighted room on the second floor of a restaurant which was not even of the second class. He would pass whole days there without going out, with a few rare books around him, and numerous glass vessels, retorts, vials and tubes, simple apparatus which he himself made. Or I go in imagination to the dark and fusty halls of the anatomical institute where we used to work till night fall by the side of our excellent chief, Johann Muller. We took our dinner in the evening, after the English fashion so that we might enjoy more of the advantages of daylight."

Johann Muller: The mention of Johann Muller is worth a moment's digression. Muller, the son of a poor shoemaker, was born at Coblentz in July, 1801. Perhaps it was the meagerness of his worldly possessions, for have not all the followers of Saint Crispin been men of lowly estate, that served to bring out the true metal of his character. Surmounting the disadvantages and lack of opportunity of youth he became eventually one of the great teachers and master minds of German science. The inspiration derived from a great teacher or personality is difficult to comprehend much less to explain. Harvey was influenced by his association with Fabricius; Bernard was similiary inspired by Magendie. The dominant physiological mind during the first half of the nineteenth century was that of Muller. He was the great trainer of anatomists and physiologists. Among desciples during his professorship at Berlin were Virchow, the pathologist; Du Bois Reymond and Brucke, the physiologsits; Henle, the anatomist; Helmholtz, and Leiberkuhn. All became distinguished scholars and professors in German universities. In glowing tribute to his master, Helmholtz said: "Whoever comes in contact with men of the first rank has an altered scale of values in life. Such intellectual contact is the most interesting event that life can offer."

Muller's manner and gestures in the classroom reminded his hearers of a Catholic priest. The way he impressed the scientific men of his time is best evidenced by the numerous tributes accorded his memory. Verworn says: "He is one of those monumental figures that the history of every science brings forth but once. They change the whole aspect of the field in which they work and all later growth is influenced by their labors." And of his monumental work the Handbook of Physiology, which appeared in 1833, the same eulogist writes: "This work stands today unsurpassed in the genuinely philos-

ophical manner in which the material, swollen to vast proportions by innumerable special researches was for the first time sifted and elaborated into a unitary picture of the mechanism within the living organism. In this respect the handbook is not only unsurpassed but unequalled."

To sum up and to sift the accumulated knowledge of a department of scientific endeavor is truly a herculean task, one requiring the impartiality of a judge and energy and zeal for the work that amounts to genius. Haller performed a similar service for physiology in his day.

Johann Muller a "vitalist:" Attempts have been made to account in some more or less satisfactory way for the phenomena of life. Two theories have engaged the attention of scientists—vitalism and the chemico—physic or mechanistic theory. The majority of scientists of the present day maintain that living organisms are mere machines, as opposed to the theory of vitalism which presupposed the presence of some "life" principle. The chemico-physicist today sees nothing that may not be explained by the ordinary laws of physics and chemistry. The tendency in all science is to express the less simple in terms of the more simple. Every activity of living substance is accompanied by molecular or chemical changes in its composition, such as oxidation (combustion) so that chemical activity, which is the source of energy, and all vital manifestations are physico-chemical in nature. Haller, in 1700, defined vitalism or vital force as a life principle which possessed the ability to originate energy, which meant that an organism was not wholly dependent upon the food which it consumed for its energy.

The scientists of the period 1810 to 1850 were, for the most part, adherents to the mechanical explanation of the phenomena of life. During this time also, the vitalistic theory was not without its advocates who were among the pupils of the great idealist philosopher, Schelling. Such men as Johann Muller, the physiologist; Von Baer, the embryologist, and Liebig, the chemist, were said to be close adherents to the vitalistic theory. It was not, however, until 1847, the date of publication of the researches of Helmholtz on conservation of energy that vitalism received a stunning blow. Sir Michael Foster explains Muller's vitalistic leanings by declaring that, "He was a vitalist only in the sense that he was theoretically of opinion that even when the physico-chemical analysis of vital phenomena had been pushed as far as it could, there would still remain a large residue which could not be explained by any such analysis, however complete." In view of the fact that his great pupils were noted for their effort to solve physiological problems by physico-chemical means, the explanation is plausible. It might be stated that Schwann, as well as other pupils of Muller, had recourse to vitalistic explanations only when their means of analysis proved inefficient.

"The graven image, vitalism," says Starling, "has acted as a continual check on the growth of man's knowledge and control of his environment just as the hypothesis of special creation would impede all research into the relationships of animals and plants, so vitalism would stay the hand of the physiologist in his endeavors to determine the changes which occur within the living organism."

Muller died in 1857. Virchow, at his obsequies in Berlin, indulged in the following panegyric over his master:

"My feeble powers have been invoked to honor this great man, whom we all, representatives of the great medical family, teachers and taught, practitioners and investigators, mutually lament and whose memory is still so vividly with us. Neither cares by day nor labors by night can efface from our mind the sorrow which we feel for his loss. If the will made the deed, how gladly would I attempt the hopeless task of proper appreciation. Few have been privileged, like myself, to have this great master beside them in every stage of development. It was his hand which guided my first steps as a medical student. * * * But how can one tongue adequately praise a man who presided over the whole domain of the science of natural life; or how can one tongue depict the master mind, which extended the limits of his great kingdom until it became too large for his own undivided government? * * * We have to inquire what it was that raised Muller to so high a place in the estimation of his contemporaries; by what magic it was that envy became dumb before him, and by what mysterious means he contrived to enchain to himself the hearts of beginners and to keep them captive through many long years? Some have said that there was something supernatural about Muller, that his whole appearance bore the stamp of the uncommon. That this commanding influence did not wholly depend on his extraordinary original endownments is certain from what we know of the history of his mental greatness."

Years of Discovery: Such was the mind from which Schwann derived his inspiration. The middle of the nineteenth century was the golden age—the Periclean age—of physiology in Germany. To quote further from Schwann's biographer (Henle): Those were great days. The microscope had been brought to such a state of perfection that it was available for accurate scientific observation. The mechanics of its manufacture had besides just been simplified to such a degree that its cost was not beyond the means of the enthusiastic student even of limited means. Any day a bit of animal tissue, shaved off with a scalpel or picked to pieces with a pair of needles might lead to important ground breaking discoveries."

After the publication of his work on the cell theory, Schwann was appointed professor in the University of Louvain, where he remained nine years, after which he received a similar appointment in the University of Liege. His "Microscopical Researches into the Accordance in the Structure of Plants and Animals," though of somewhat cumbersome title, is one of the great classics of biology. He proves the identity in structure of animals and plants by direct comparison of their elementary parts. His conclusion is that "the elementary parts of all tissues are formed of cells in an analogous, though very diversified manner, so that it may be asserted that there is one universal principle of development for the elementary parts of organisms, however, different and that this principle is the formation of cells."

Virchow and "Cellular" Pathology: Any account of the cell theory must needs be incomplete with the omission of the name and work of Rudolph Virchow. Virchow was born in 1821 of humble parentage, his father eking out a livelihood from the combined oc-

cupations of farmer and small shopkeeper. The son who received the academic training of his day was of an active restless temperament. Virchow's was a mind open to new ideas, of liberal and independent views on medicine, politics and religion. His open sympathies with the reform tendencies in 1848 were such that he was obliged to leave Berlin for Wurzburg, where he taught pathology and did much original work therein. He was recalled to Berlin in 1856, when he was made professor of pathology in the university. The scope of his activities may be seen when it is considered that he was also a member of the Reichstag, where he became leader of the opposition and a vigorous antagonist of Bismark. As chairman of the finance committee, Virchow is credited as the author of the Prussian Budget system. He took a leading part in the politics of his city; and the fact that from being one of the most unsanitary cities Berlin has come to be one of the most healthful spots has been attributed in great measure to his insistance on sanitary reform. Virchow stands in much the same relation to pathology as Schwann to histology. He has been called the "Father of Modern Pathology." He established "The true and fertile doctrine that every morbid structure consists of cells which have been derived from pre-existing cells," or as he himself expressed it: "Omnis cellula e cellula." His chief work was his cellular pathology published in 1858; in it he applied the cell theory to diseased tissues. He died in 1903.

The cell theory incomplete as first announced: When William Harvey published his discovery of the circulation, so complete was his self-appointed task that little was left for future workers. The glycogenic function of the liver is known and understood by us practically as proclaimed by Claude Bernard. The cell doctrine has a vastly different history. As announced by it's co-founders, it was far from being complete. Among other inaccuracies they attached too much importance to the cell wall. The word "cell" implies a walled enclosure. The cell of honeycomb or the cell of a penal institution are examples which suggest themselves. The fundamental declaration that all parts of plants and animals are built of similar units or structures has been substantiated. This is perhaps the only portion of the theory that has not been profoundly changed.

The Discovery of Protoplasm: Perhaps of equal importance to the cell-theory was the recognition of protoplasm. Huxley called it "the physical basic of life." Felix Dujardin recognized this substance, which is the basis of vital activity, in 1835. He discovered in lower animal forms a jelly-like substance which he called "sarcode." Dujardin was born in 1801 at Tours, France. He was trained to follow the trade of his father, namely, that of watchmaker, and the manual dexterity thus acquired served him in good stead in the later vocation of his life. He was an adept with the microscope and possessed no small ability as sketch artist. He showed early a love for the natural sciences. His contributions to science cover a range of topics. He was perhaps the greatest authority of his day on protozoology. He died in 1860.

Schleiden saw protoplasm but called it gum. Cohn, in 1850, taught that "protoplasm" of plants and "sarcode" of lower animal life were the same thing. Max Schultze, in 1861, confirmed Cohn's

position and added that the cell consisted of little units of protoplasm surrounding a nucleus. The nucleus was first described by Fontana, in 1871. It was regarded as a normal element of the cell by Robert Brown in 1883. It was eventually seen that many cells, especially animal cells, are without a cell wall, hence the conclusion that the so-called "wall" is not an essential feature of the "cell." When the cell wall is absent the protoplasm is the cell. The nucleus was found to be within the substance of the cell and not within the cell wall. Schultze defined the cell as a globule of protoplasm surrounding a nucleus. From being regarded as an element of structure merely, the cell has come to be recognized as the physiological unit within which all physiological activity takes place.

Perhaps the most authoritative as well as the most recent definition of protoplasm is the following significant paragraph by Starling:

"Though it may be convenient to have a word such as protoplasm signifying simply 'living material,' it is important to remember there is no such thing as a single substance—protoplasm. The reactions of every cell as well as its organization are the resultant of the molecular structure of matter of which it is built up. The gross methods of the chemist show him that the composition of the protoplasm of the muscle cell is entirely different from that of a leucocyte or white blood corpuscle. The finer methods of the physiologist show him that every sort of cell in the body has its own manner of life, its own peculiarities of reaction to uniform changes in its surroundings. No individual will react in exactly the same manner as another individual even of the same species, and the reactions of the whole organism are but the sum of the reactions of it's constituent cells. There is not one protoplasm therefore, but an infinity of protoplasms and the use of the term can be justified only if we keep this fact in mind and use the word merely as a convenient abbreviation for any material endowed with life. Even in a single cell there is more than one kind of protoplasm. In its chemical characters, in its mode of life, and in its reactions, the nucleus differs widely from the cytoplasm. Both are necessary to the life of the cell and both must be regarded according to our present ideas as 'living.' In the cytoplasm itself we find structures or substances which we must regard as on their way to protoplasm or as products of the break down of protoplasm; but in many cases it is impossible to say whether a given material is to be regarded as lifeless or as reactive living matter. Even in a single cell we may have differentiation among its different parts, one part serving for the process of digestion while other parts are employed for purpose of locomotion. Here again there must be chemical differences, and therefore different protoplasms."

A statement of the cell theory at the present time (1913) must include four conceptions: (1) The cell as a unit of structure; (2) The cell as a unit of physiological activity; (3) The cell as embracing all hereditary qualities within its substance; (4) The cell in the historical development of the organism."

Students of cytology have sought to find out if any uniformity of organization of protoplasm exists. Accordingly we have a number of explanations or theories regarding its structure. Altmann proposed the granular theory. By the employment of certain hardening reagents he demonstrated dense masses of spherical or rod-shaped granules in all the cells of the body. In these he located the various vital functions, the sum total of which constitute the life of the cell.

He further maintained that these granules could come only by division of pre-existing granules. He parodied Virchow's famous phrase omnis cellula e cellula into omne granulum e granulo.

The fibrillar theory presupposes net-work or clusters of fibrils known as "spongio-plasm" (sponge plasm) in contra-destinction to clear or structureless matter filling in the meshes of the net to which the name "hyaloplasm (glass plasm) has been given.

In the Alveolar Theory of Butschli the author regards the so-called granules as products manufactured by the hyaline protoplasm and stored up as spherules so that the protoplasm between the droplets form an alveolar partition—hence the name of the theory.

Discussing the question as to the fluidity of protoplasm Starling regards it as "essentially fluid in character, the form and rigidity which are acquired by most cells being due to chemical and physical differentiation occurring in its fluids."

The cell consists of cytoplasm and nucleus. Cytoplasm (cell plasm) is a term formulated by Kolliker in 1863. Though not so applied when first used, it has come to mean the living substance of the cell body other than the nucleus. Cytoplasm contains, for the most part, substances apparently foreign to the cell proper. In the cytoplasm of plant cells, for example, are stored up starches and oils. Most nerve cells contain various shaped bodies which, it is alleged, represent stored up energy. The passive bodies in the cytoplasm are supposed to represent some form of latent energy upon which the cell may draw. In the cells of any green leaf are to be found spherical masses which play a most important role in the lives of not only plants but of animals as well. By the action of the sun's rays a chemical change takes place in these bodies known to botanists as chloroplasts by which carbondioxide and water are broken down, decomposed and immediately synthetized into a different substance—carbohydrate, starch, which will respond to the well known iodine test for starch. Carbohydrate is one of the food principles. Fats are also made and stored in the form of oils. In spite of the fact that the atmospheric air surrounding the plant contains an abundance of free nitrogen. The plant cells are unable to make use of it. Nitrogen must be first combined as a nitrate, become dissolved in the soil and taken up by the roots of the plants, or in the case of water plants, by special cells, before the green matter in the leaf can be transformed into protein. The plant, therefore, has power to make foods out of the chemical elements of air and water when these elements are properly combined. This is the only source of food of both plant and animal and it is the result of cellular activity.

The Nucleus: The nucleus has been recognized as a most essential part of the cell. It not only takes part in the complex process of cell division but dominates the rest of the cell. It is not my purpose to enter upon a discussion of the morphology and physiology of the animal and vegetable cell, further than it is necessary to trace the various stages of the history of its revelation from its earliest recognition to the present. The reader is referred to the numerous excellent text books on the subject.

ILLUSTRATIONS SHOW DIAGRAMATICALLY THE CELL AND INDIRECT CELL DIVISION.


Fig. 1.


Fig. 2.


Fig. 3.

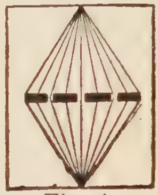


Fig. 4.


Fig. 5.


Fig. 6.


Fig. 7.

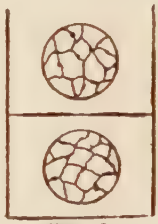


Fig. 8.

"The first change in the appearance of the nucleus which indicates that a division is about to take place, consists in a rearrangement of the chromatin net work, which now takes place on the appearance of a tangled thread (Fig. 2). The outwardly directed loops of this skein often correspond to the seperate portions into which the thread eventually breaks up. The thread gradually grows shorter and thicker, and presently becomes divided into a number of pieces known as chromosomes. In the chromosomes the shortening and thickening process is continued until these bodies arrive finally at the form of stumpy rods, each of which, often becomes bent into the form of a horse shoe. Meanwhile the nuclear membrane, breaks down, so that the hyaline substance of the nucleus becomes continuous with that of the cell body surrounding it. A fresh phenomenon now becomes visible. A spindle-shaped arrangement makes it's appearance consisting of a number of minute fibrils which connect together two points—the poles of the spindle—situated at opposite ends of the cell. The chromosomes now change their position so that they come to be in the plane of the equator of the spindle, and about this line each chromosome splits longitudinally into two great portions (Fig. 4 and 5). This splitting in the case of each chromosome takes place in the equatorial plane of the spindle, so that one member of each pair of daughter chromosomes faces towards one pole of the spindle and the second towards the other pole. The members of each pair of daughter chromosomes now begin to move away from one towards the two poles of the spindle, and as they do so the first indication of a dividing wall between the second new cells begins to make its appearance in the equatorial plane. Arriving at the poles, the daughter chromosomes begin to elongate and to put out processes which finally meet and fuse with those of their neighbors to form the chromatin reticulum of the new nuclei. (Fig. 7.) Surrounding each new nucleus, thus developing at either pole of the now rapidly disappearing spindle, a new nuclear membrane makes it's appearance; the dividing wall in the position of the equator of the spindle develops into a complete partition in the case of plants. (The animal cell is without a cell wall.) The division into two new cells is thus completed. (Fig. 8.) Each new cell is provided with a nucleus into which has entered precisely its fair share of the chromatin which was present in the parent nucleus."

—Illustration and description after Locke.

The discovery of the various dyes and tissue stains afforded a wonderful stimulous to the microscopic study of tissues as well as to bacteriological studies. It is hard to conceive of much progress in bacteriology without this aid. Dyes for staining protoplasm were first prepared in 1868. The property of taking up a stain gave rise to the invention of a number of new names for which scientists have as usual drawn freely from the Greek. To designate that protoplasm which stained deeply, we have the term "chromatin." The word "achromatin" has been applied to protoplasm, which will not absorb the dye. Certain rod-shaped bodies situated within the nucleus, which stain more deeply than any other portions are known as "chromosomes."

The Cell In Heredity—Within recent years the subject of heredity has claimed the attention of biologists and its practical application has become of intense interest to the laity, advances in our knowledge of heredity are already producing results. They have revolutionized agricultural methods as shown in the marked improvement of animals and plants. It is impossible of realization what are the potentialities in regard to the improvement of the human race. Eugenics is as yet in its infancy. The past ten years has witnessed the production of voluminous literature on eugenics and its kindred subject heredity.

Smallwood in his latest work states that "Whatever may be the ultimate analysis of the problem of heredity, there can be no hesitation in stating that the transmitted characters exist potentially in the protoplasm of the cell. From the egg of a robin only a robin will develop, from the ovum of an oak only an oak will grow and during the growth each follows its own successive developmental stages even to the minutest details. It has been well said 'nature never yet made two eggs or two sperms exactly alike.' The cells which give rise to new organisms are the germ cells, sperms and ova. These differ greatly in shape and size—some of the sperm cells being but one one-hundred-thousandths the bulk of the ovum and yet the paternal characters are easily recognized in the adult. * * * The cells of the body are divided into body plasm and germ plasm." Germ plasm might be looked upon as the immortal in man in as much as it is continuous. After the germ plasm has given rise to a new individual, some of it is left behind to participate in the formation of a new offspring, so as Davenport puts it, "There is really no inheritance from parent to child but parent and child resemble each other because they are derived from the same plasm, they are chips of the same old block; and the son is half-brother of the father by another mother."

As the cell has been called "The physiological unit," and protoplasm "the physical basis of life," the chromosomes have been proven the physical basis of heredity. They are very definite and important organs. The number which make their appearance at each cell division is the same in all the cells of any given creature and is constant for the cells of the members of any given species.

"The remarkable fact," says Wilson, "has been established that every species of plant or animal has a fixed and characteristic num-

ber of chromosomes, which regularly occurs in the division of all of its cells, and in all forms arising by sexual reproduction, the number is even."

Whatever the offspring is, it is potential in the fertilized ovum. If this is the contribution of each parent, the role performed by the mother is that of custodian of her embryonic charge until birth. Her power to alter it in any way is as futile as that of the father. The parent is rather the trustee of the germ plasm than the producer of the child. Sir Michael Foster once said, "The animal body is in reality a vehicle for the ova; and after the life of the parent has become potentially renewed in the offspring, the body remains as a cast-off envelope whose future is but to die." The germ plasm is "the lighted torch handed on from one runner to another." Et quasi cursores vitai lampada tradunt. This equally true of plant life, where the plant matures and dies leaving the future offspring potentially in the seed. How characteristics are transmitted from ancestor to offspring is not known.

NOTE:—It has been estimated that the number of cells entering into the composition of the body of an adult human being is about twenty-six million five hundred thousand millions (26,500,000,000,000).